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Commercially important grenadiers of the North Atlantic

by

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SUMMARY

Economically important Grenadiers of the North Atlantic (Coryphaenoides rupestris and Macrourus berglax)

With the loss of traditional fishing grounds as a result of the introduction of 200 miles EEZs by coastal states the German high seas fishery developed increasing interest in more offshore resources in the North Atlantic.

This report contains an overview on the present knowledge of the two commercial grenadier fish species, the Roundnose Grenadier and the Roughhead Grenadier, in the North Atlantic, based on a review of related international literature and results of investigations carried out from the Federal Republic of Germany.

Both species inhabit the deeper parts of the continental slope from the waters off Nova Scotia, Newfoundland and Labrador, via the Davis Strait, West and East Greenland, Iceland, to the waters west of Great Britain and Ireland, and along the Norwegian coast to Spitsbergen and the Barents Sea. Their areas of distribution overlap to a large extent. However investigations show that research samples and catches of the commercial fisheries off East Greenland, NW Iceland, northern Norway and Spitsbergen consist primarily of Macrourus berglax whereas in the other areas mentioned Coryphaenoides rupestris prevails. Unfortunately these two species are not listed separately in fisheries statistics.

The report provides information on the horizontal and vertical distribution of the grenadiers, on the length and age composition in scientific and commercial catches, on growth, reproduction, food and parasites. For the Roundnose Grenadier a brief review is given on the assessments made for the stocks in the Northwest Atlantic and on the management of these resources through catch limitations (TACs) in the area of the Northwest Atlantic Fisheries Organization (NAFO). Furthermore some information is provided concerning product development from the Roundnose Grenadier.

1. Introduction

Because of the decrease of catches from the traditional commercial fishing grounds of the North Atlantic Ocean and, in particular, because of the introduction of the 200-mile EEZs by coastal states, German deepsea fishery has been forced to turn, in part, to fishing for species hitherto not at all taken or taken only to a small extent, and to look for new fishing grounds. Fisheries research is making great efforts to support commercial fishery through appropriate scientific work^{and advice}/. In addition to the blue leng [Molia byrkelange], the Greenland halibut [Reinhardtius hippoglossoides], the blue whiting [Micromesistius poutassou] and various other fish species, the grenadiers belong to the "new" species brought ashore in increasing numbers by German commercial fishing vessels and enjoying increasing appreciation by consumers.

About 300 species of grenadiers are known on a worldwide basis; 80 of these species occur in the Atlantic. However, only two species (Coryphaenoides rupestris and Macrourus berglax) are of commercial importance in the North Atlantic Ocean; a further species (Nezumia bairdi) is frequently taken in the western North Atlantic.

The present report gives an overview of the present knowledge of these valuable resources based on a review of the pertinent literature and the results of investigations carried out by scientific institutions in the Federal Republic of Germany.

2. Fisheries and yields

Directed commercial fishing of grenadiers was started in 1965 with scientific work done by Soviet trawlers along the continental slope between the Grand Bank off Newfoundland and Baffin Island at depths between 400

and 1370 meters (Pechenik and Troyanovsky, 1970). This fishery developed rapidly, and the grenadiers taken found a ready market. As the fishery statistics of the ICNAF—which provide data on grenadiers since 1967—demonstrate, Soviet fishery in the North Atlantic has brought ashore considerable quantities of these fishes year after year (Table 1). The catches varied rather greatly over the years, amounting to between about 15,000 tons and 36,000 tons up to 1978. 1971 was an exceptional year when the catch amounted to 80,000 tons. In addition to the Soviet Union, whose share in the total catch up to 1977 amounted without exception to > 85 per cent, grenadiers have been fished also by the German Democratic Republic, Poland and Rumania, as well as, more recently, by the Federal Republic of Germany in rather considerable quantities. Data available since 1978 must be regarded with some caution, since fishery-political considerations (quotas, economic zones) greatly affect the reporting of these data, and [in some instances] they may well be falsified. The quantities reported as having been brought ashore have greatly decreased since 1979.

In most years, grenadier fishery is concentrated mainly on the waters northwest off Newfoundland (ICNAF/NAFO area 3K). In a number of years—in particular, in 1971 and 1975—considerable quantities of grenadiers were taken also further north off Labrador in areas 2G, 2H and 2J. Off Baffin Island (SA 0), up to 6000 tons have been taken in some years; however, since 1977, the quantities taken have been negligible. In the waters off western Greenland (SA 1, C-F), fishing for grenadiers on a large scale was started in 1970, and the quantities brought ashore mostly varied between 2000 and 6000 tons/year, until they dropped to insignificant levels since 1981.

According to statistical data available from ICNAF/NAFO, the catches of this fishery in the western North Atlantic consisted of rock grenadiers (Coryphaenoides rupestris).

Table 1 - Catches of grenadiers brought ashore from the North Atlantic, 1967 - 1983 (in tons)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983 ²⁾
Federal Republic of Germany						17 ¹⁾	-	199	33	148	693	6780	6812 ¹⁾	1752	353	11	+
German Democratic Republic	1408	4735			1185	445	2519	4570	2891	678	674	1801	480	898	1407	1640	2586
Denmark (Greenland)							11	5	6	1	10	32	21	32	39	37	22
Newfoundland										16	15	9	4 ¹⁾	-	-	-	-
Poland					105	270	294	181	1499	101	-	51	96	36	18	15	?
Romania											7	108	-	-	-	-	-
USSR	17031	32808	15043	29389	82459	31765	19624	35779	27949	28152	16922	17760	7307	1119	5747	2732	979

SA 0	1129	5996	2642	545	4172	5796	1054	2661	204	2610	721	-	106	32	87	43	46
SA 1	6	284	68	5980	4132	2311	3830	9657	4749	5893	2214	5839	6833	1752	392	48	22
SA 2	1085	7104	651	468	56996	3109	6744	5560	11779	6682	3328	5437	4563	1498	3123	1635	1541
SA 3	16219	24159	11682	22396	18447	21281	10820	22856	15646	13911	12058	15265	3218	555	3962	2709	1976
Totals	18439	37543	15043	29389	83747	32497	22448	40734	32378	29096	18321	26541	14720	3637	7564	4435	3587

1) Supplemented with data from national [FRG] statistical material

2) preliminary data

Table 2 - Catches of grenadiers brought ashore from the North Atlantic, 1972 - 1983 [after ICES Bull. Stat. 37 (1972) - 66 (1981) and FAO Yearbook Fish. Stat. 56 (1983)], in tons.

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Federal Republic ¹⁾ of Germany	47	236	52	18	3	270	2089	3397	1234	3535	1152	270
German Democratic Republic		68	77	752	41	100	41	36	13	17	3	-
Iceland		7	1		34	11	11	24	14	16	59	95
Poland	82		19	6	2	11	19					
USSR		1047	18440	29974	4986	10635	13331	6169	17482	2955	12651	10300

1) Supplemented and corrected after national [FRG] statistical material

Grenadiers are taken also in the eastern North Atlantic, even if in considerably smaller quantities than in the western North Atlantic (Table 2). In the Bulletin Statistique des ICES, grenadiers are listed separately for a number of countries only since 1972, and a fishery-statistical distinction between the rock grenadier and the roughhead grenadier is not made at all, although in that part of the Atlantic both species are of importance for commercial fishery. Soviet fishery takes the greatest share of grenadiers also in the eastern North Atlantic. The great majority of these catches are taken south of the Reykjanes Ridge (ICES subarea XII).

The development of grenadier catches since 1967 from the western and eastern North Atlantic, respectively, is illustrated in Figure 1. It is evident (1) that utilization of the eastern North Atlantic was started several years later than of the western North Atlantic, (2) that the catches taken from the western North Atlantic were significantly greater up to 1979, and (3) that in 1980 for the first time more grenadiers were caught in the eastern North Atlantic than in the western North Atlantic.

A summary of the statistics on grenadier catches made by vessels of the Federal Republic of Germany since 1972 (in which year detailed statistical data were collected for the first time through log entries) is presented as

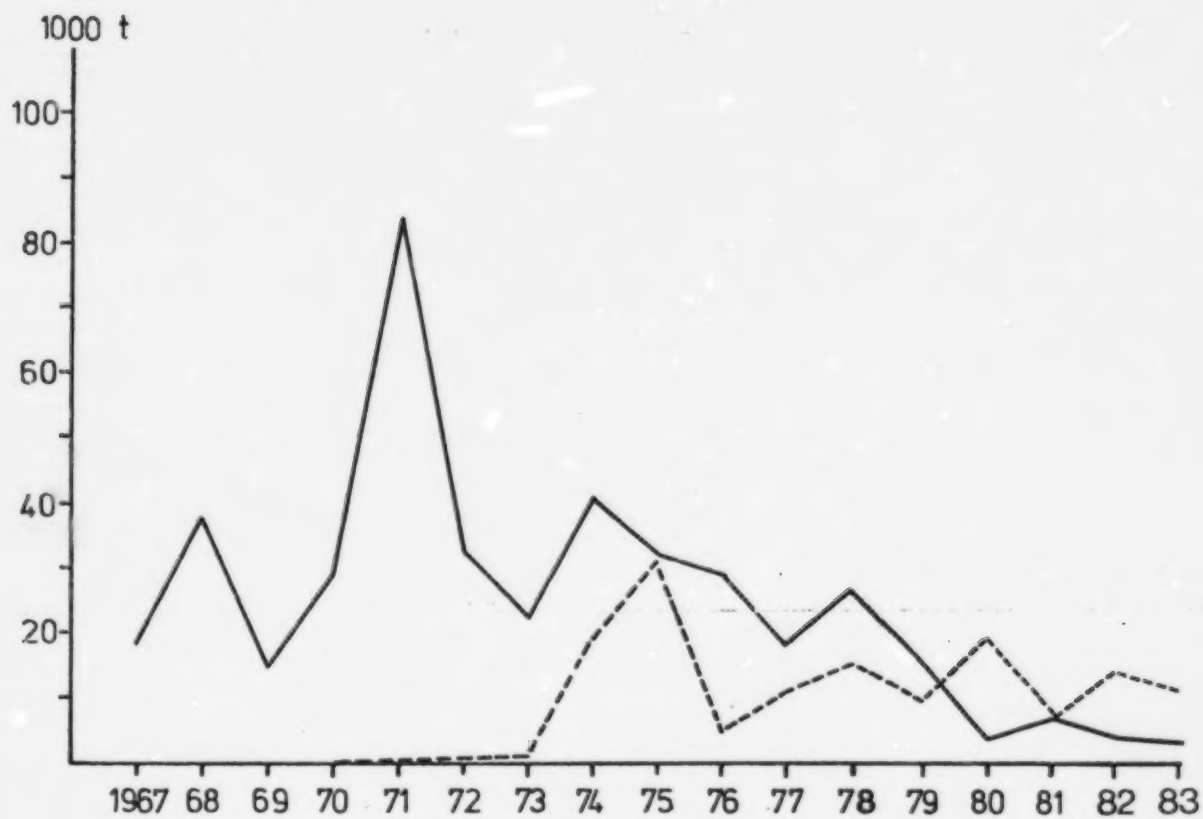


Figure 1 - Catches of grenadiers brought ashore from the northwestern Atlantic (continuous line) and the northeastern Atlantic (broken line) (after FAO Year-book of Fishery Statistics).

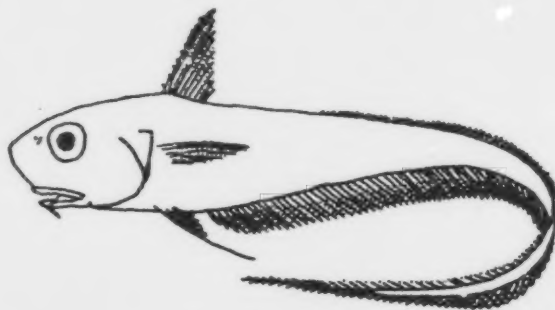
Table 3 - Catches of grenadiers brought ashore by vessels of the Federal Republic of Germany, 1972 - 1984, in tons.

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
North Sea/Shetlands	1	-	-	-	-	-	2	1	11	-	0	3	3
Hebrides/Rockall	-	-	-	-	-	-	4	26	27	92	-	0	-
Coast of Norway	-	-	-	-	1	-	10	7	6	3	1	6	0
Faroe Islands	1	8	+	-	-	1	+	15	7	146	23	3	5
Iceland/Reykjanes Ridge	40	180	38	-	-	-	-	43	29	29	18	-	5
Greenland (east coast)	5	48	14	18	2	269	2073	3305	1155	3266	1110	258	115
Greenland (west coast)	13	-	-	33	147	519	5809	6812	1720	334	12	+	+
Labrador	-	-	5	-	-	157	961	-	-	-	1	-	-
Newfoundland	4	-	193	-	1	18	2	-	32	-	-	-	23
Totals	64	236	230	51	151	964	8861	10209	2987	3890	1165	270	151

Table 3. The most important fishing grounds are located off western and eastern Greenland. The data on quantities taken from these waters—in particular, those for 1978 and 1979—may well be tainted by fishery-political considerations. Up to 1975, the grenadiers taken were mainly processed into fishmeal; however, since then, the catches have been marketed to an increasing extent as table fish. The catches taken off eastern Greenland (Dohrn Bank) consist of roughhead grenadiers (Macrourus berglax); those taken off western Greenland consist mainly of rock grenadiers (Coryphaenoides rupestris). However, in fishery statistics, these two species are not listed separately.

3. Rock grenadier (*Coryphaenoides rupestris*)

The rock grenadier is a demersal fish with a relatively short trunk and long, laterally compressed, tapering tail without tail fin. The head is relatively large; the eyes are relatively large; the snout is short and blunt (Figure 2). The largest specimens of this species hitherto taken measured up to 130 cm in length.



Coryphaenoides rupestris

Figure 2 - Rock grenadier

3.1. Distribution (Range)

The rock grenadier occurs along the slopes of the continental shelf and on the offshore Ocean banks in the North Atlantic at depths of between 180 m and > 3000 m. As is shown by Figure 3, the range of distribution stretches from off Cape Hatteras off the east coast of North America by way of Newfoundland, Labrador, Baffin Island, western and eastern Greenland, Iceland, the Barents Sea, northern Norway, northern North Sea and Skagerrak by way of the waters west of the British Isles to the inner Biscaya and Cape Finisterre. In German studies carried out in 1982 on the mid-Atlantic Ridge, several rock grenadiers were taken down to a depth of 3200 m. (However, these fishes might well have been caught while the net was hauled in.) These findings are in agreement with those reported by Gushchin and Kukuev (1980) dealing with relatively large catches of C. rupestris in the area of the mid-Atlantic Ridge between 45° and 60°N.

Figure 4 shows the fishing grounds where rock grenadiers were taken in the years 1955 to 1984 by the German fishery research vessels "Anton Dohrn" and "Walther Herwig." It should be noted that these research voyages—apart from a few exceptions beginning in 1974 in the waters west of the British Isles—were not directed toward studying grenadiers. On the whole, these catch results confirm and supplement our recent knowledge regarding the distribution of C. rupestris.

In the western North Atlantic, the richest fishing grounds for grenadiers are located, according to Savvatimsky (1969), along the north-eastern edge of the Grand Bank of Newfoundland, off Labrador (in particular, along the edge of the Hamilton Inlet Bank), and off the northern part of Labrador as well as south-east of Baffin Island (cf. also Figure 5, from Pechenik and Troyanovsky, 1970). Atkinson et al. (1982) have published a map of the main

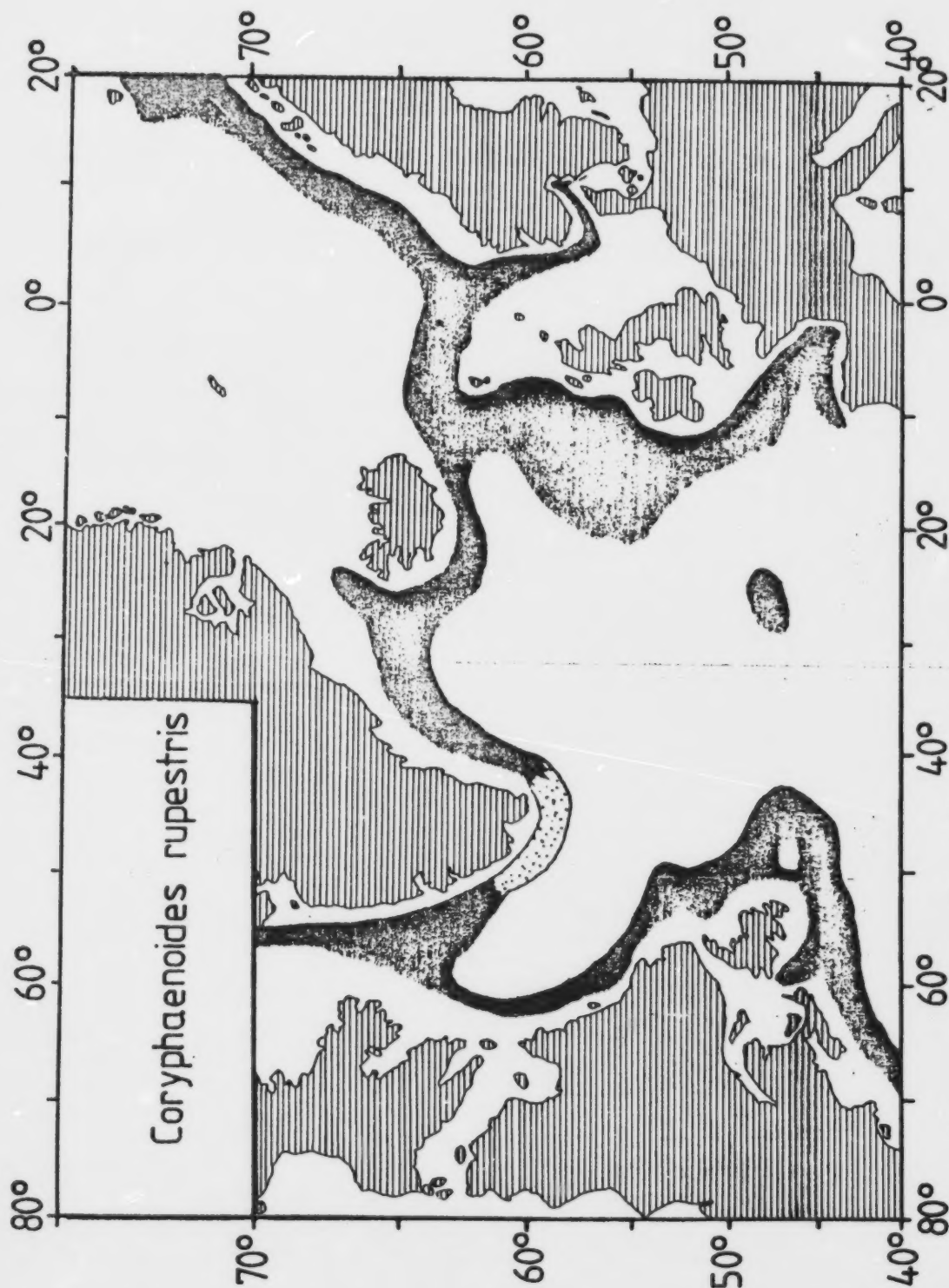


Figure 3 - Distribution of the rock grenadier in the North Atlantic

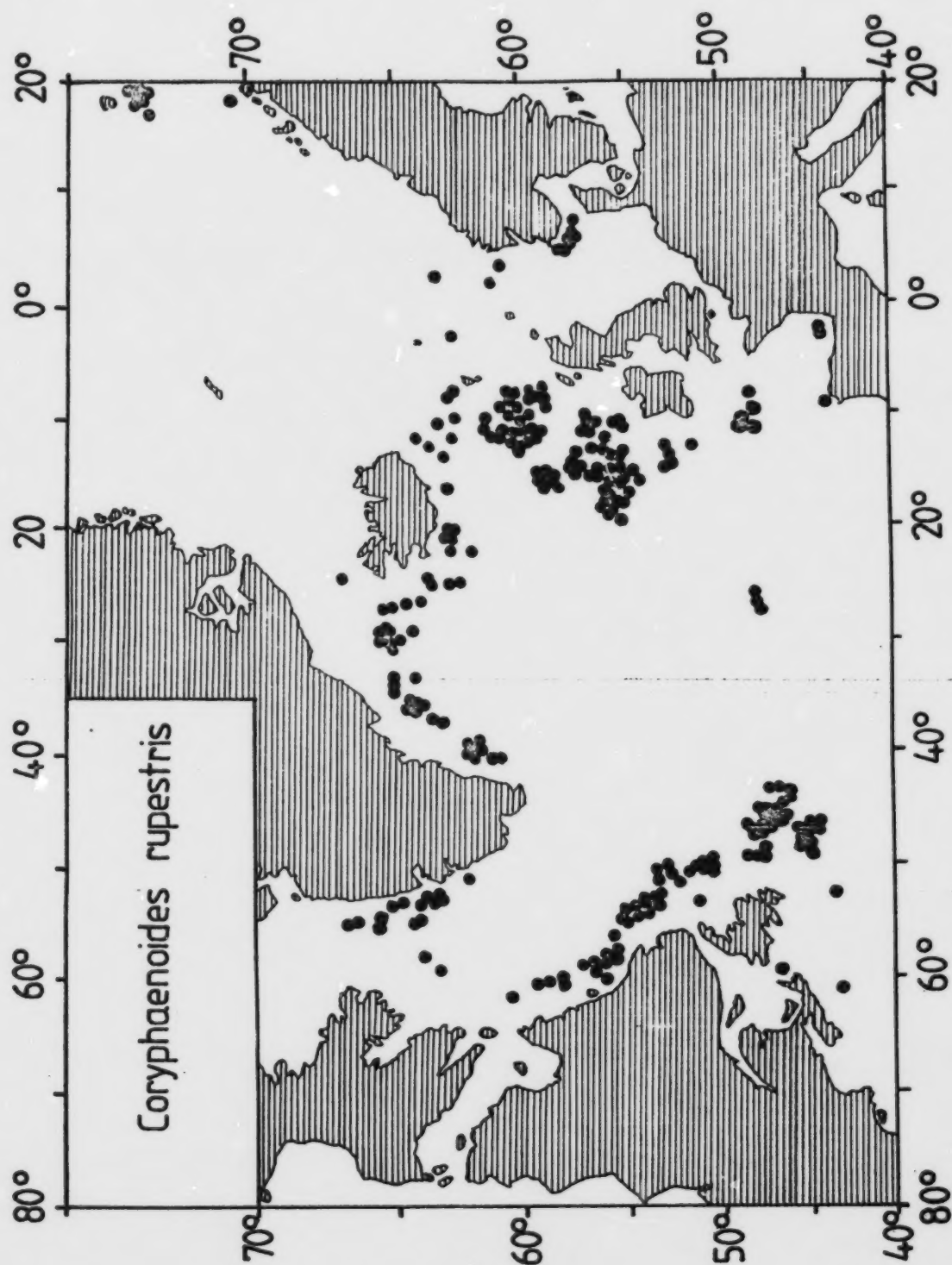


Figure 4 - Fishing grounds for the rock grenadier used by research vessels of the Federal Republic of Germany, 1955 - 1984

grenadier fishing grounds in the Davis Strait, 1968 - 1977, which is reproduced in this paper as Figure 6.

Canadian scientific catches with fishery vessel "A.T. Cameron," 1958 - 1973 (Parsons, 1976a; 1976b) have revealed similar results, and demonstrated significant occurrences of grenadiers also along the eastern edge (Flemish Cap) and the southern edge of the Grand Bank off Newfoundland. Grenadiers have been caught also on the shelf slope off Nova Scotia, while this species is missing in the Gulf of St. Lawrence (Figure 7).

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Rock grenadiers may be encountered at depths between about 180 m and > 2000 m, with the number of fishes taken above a depth of 400 m being only small; fishery for dense concentrations is usually carried out at depths between 500-600 m and 1300 m (Savvatimsky, 1971; Zilanov, 1976; Parsons, 1976b).

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Forest et al. (1978) found no rock grenadiers off Baffin Island above 370 m; they were rare between 370 and 550 m; below the latter level, their numbers increased to maximal density at a depth between 900 and 1280 m. According to Savvatimsky (1977), the rock grenadier at times occurs at bathypelagic levels, i.e. this fish is frequently encountered in the free water close to the bottom and also at somewhat higher levels, where it follows its planktonic food (cf. Section 3.5.). These concentrations in the free water may measure up to 300 to 500 m in thickness and cover a wide area.

Soviet fishery for this grenadier is carried out mainly during the second half of the year, when the fish migrate from the depths to feed in the more shallow zones of the shelf slope and exhibit increasing deposits of fat (Zilanov, 1976). Later on, this fish appears to return to greater depths, where it can not (yet) be caught by commercial fishery. These fishes represent mainly sexually immature individuals (cf. Section 3.4.). Savvatimsky (1969) has reported 700 - 850 m as depths with best catches on the Newfoundland

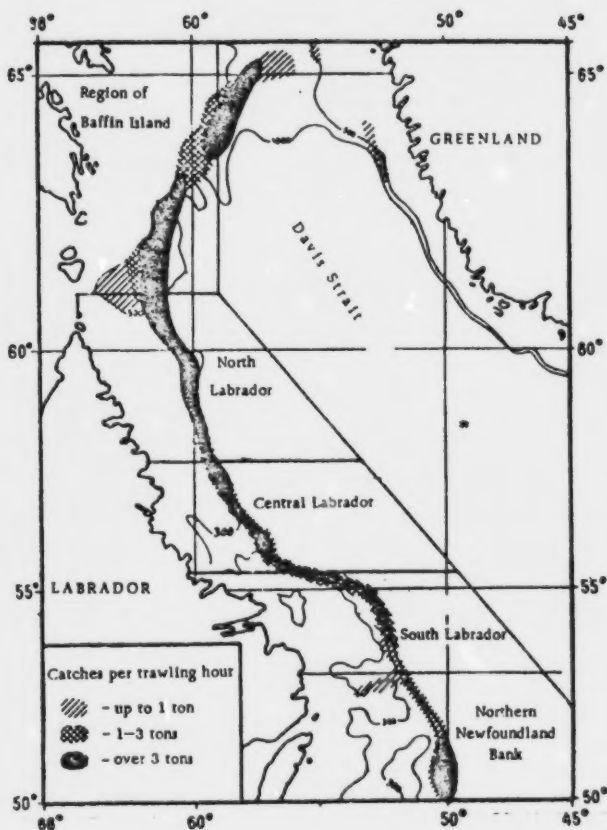


Figure 5 - Distribution of the rock grenadier in the area between Newfoundland and Baffin Island (from Pechenik and Troyanowskii, 1970; cf. also A. Meyer, 1972)

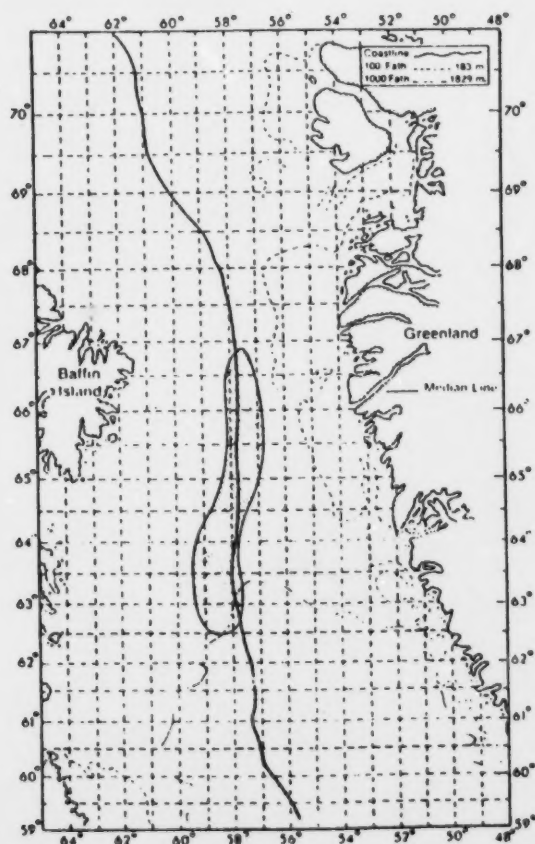


Figure 6 - Main fishing grounds for the rock grenadier in the Davis Strait, 1968 - 1977 (from Atkinson et al., 1982)

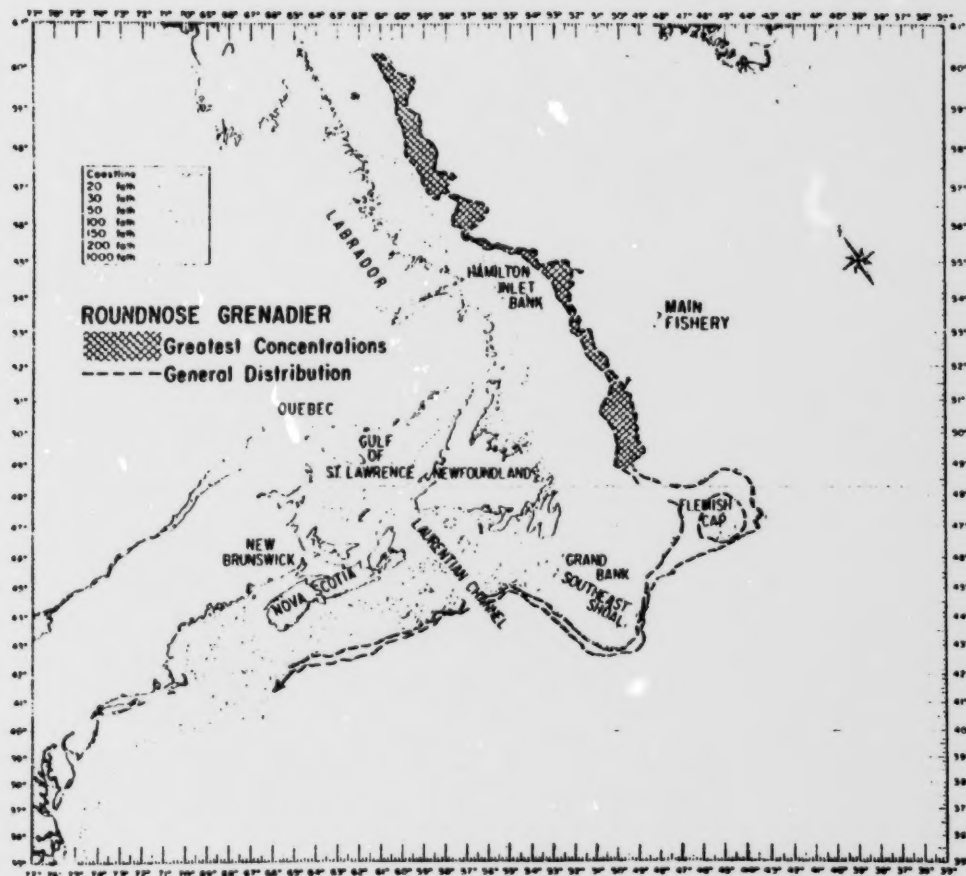


Figure 7 - Distribution of the rock grenadier in front of the coast of Canada as indicated by research catches (from Parsons, 1976b)

Bank and off Baffin Island; in the latter area, the zone with best catches was found at 1000 - 1100 m during July and August of 1968 (Figure 8). According to observations reported by the latter author, grenadiers may be caught at any time of the day; however, the catches are higher, on average, in the early hours of the morning than during the afternoon and during the night; they are lowest during the hours before noon (Figure 9).

The water temperatures in the zones with grenadier concentrations amount mainly to 3.5 - 4.5°C.

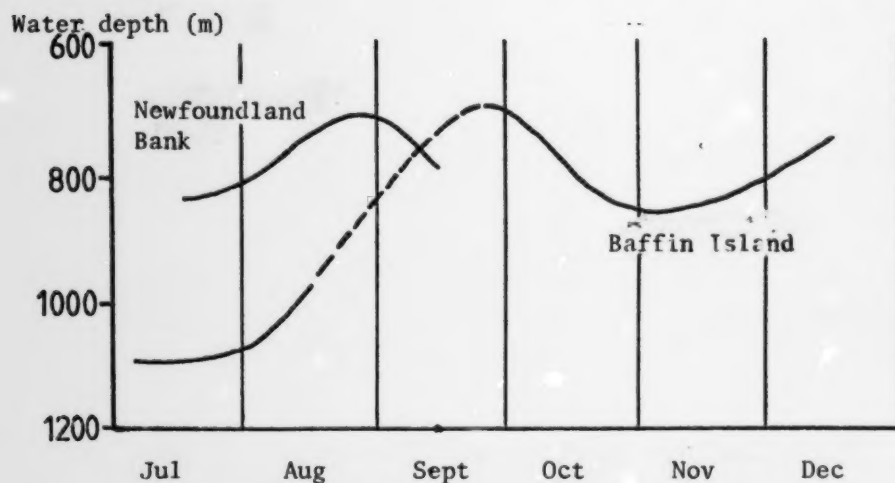


Figure 8 - Depths yielding best catches of rock grenadier in USSR fishery, 1968 (from Savvatimsky, 1969)

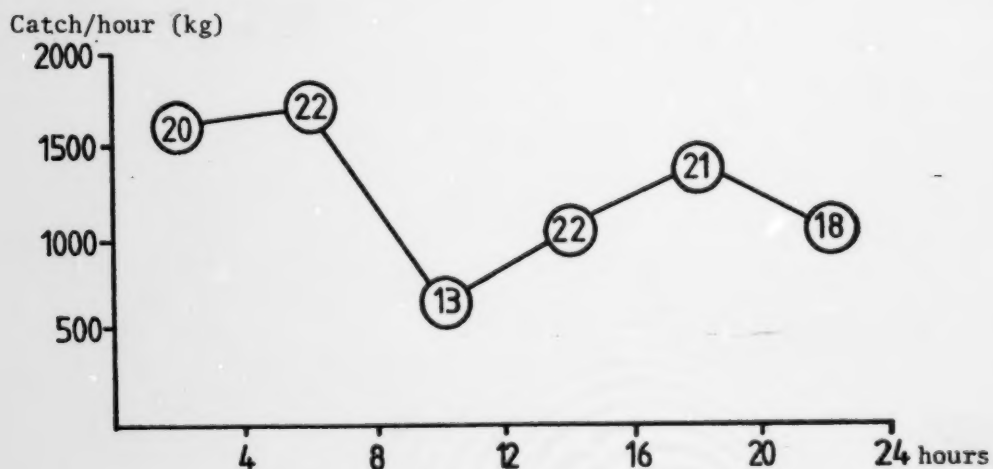


Figure 9 - Variations of mean catches with the time of day in USSR fisheries, 1968, in front of Baffin Island (the circled numbers indicate the numbers of hauls) (after Savvatimsky, 1969)

The afore-described findings on this grenadier have been largely confirmed by the comprehensive stock density determinations of demersal fishes carried out by the German research vessels "Anton Dohrn" and "Walther Herwig" for more than ten years on the Labrador shelf; these counts, to be sure, have dealt mainly with the Atlantic cod and the rosefish (ocean perch). C. rupestris was encountered only at a depth below 425 m in the research hauls, while the grenadier catches in the more shallow waters consisted of roughhead grenadiers (Macrourus berglax) and, to a lesser extent of Nezumia bairdi. At the depths at which the rock grenadier was caught, the water temperatures amounted to 3.5 - 3.9°C.

The grenadier occurrences off western Greenland have been investigated to a far lesser degree. The average catches of rock grenadiers are significantly smaller than those taken off Labrador. Fishing is possible mainly along the shelf slopes off the banks north of about 63°N (Danas Bank to Halibut Bank), while, further south down to southeast Greenland, steep edges that can be fished only with difficulty predominate, and frequent ice covering impede fishing. Off the afore-mentioned banks, C. rupestris has been taken down to depths below 380 m (Figure 10); the best scientific catches of the fishery research vessel "Walther Herwig" off Fyllas Bank (2.25 t/30 min., July 1980) were made at a depth between 600 and 700 m. The range of the rock grenadier is located within the area of the relatively warm Irminger Stream component of the west Greenland Stream with bottom water temperatures around 3.8 - 4.9°C, and, occasionally, also higher temperatures.

Off the coasts of eastern Greenland, C. rupestris actually is widely distributed at depths below 400 m (Figure 4), but is caught there usually only in small numbers. The greatest German scientific catches made by the

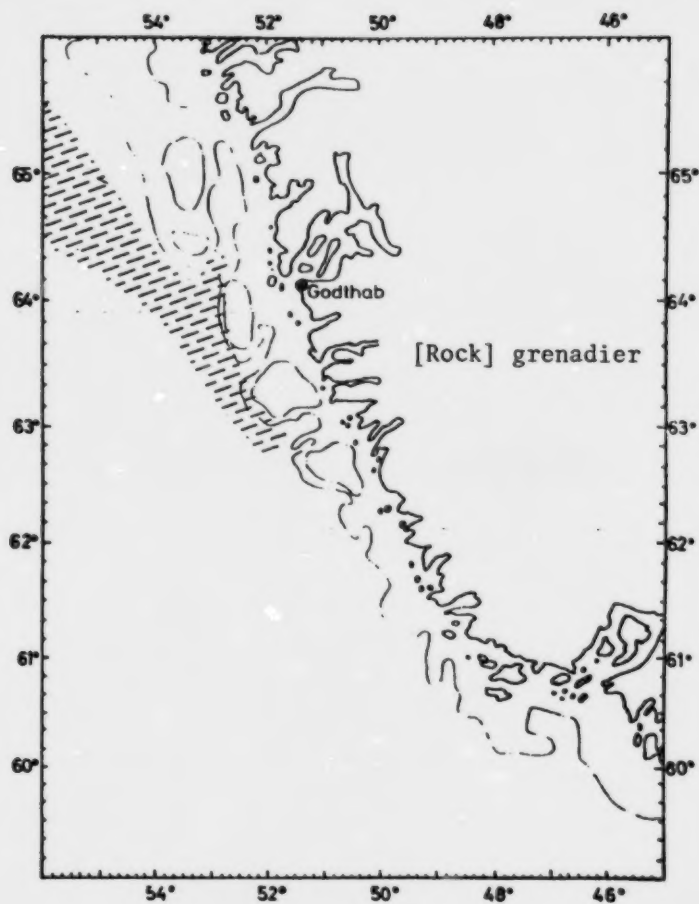


Figure 10 - Area of distribution of the rock grenadier in front of western Greenland according to catches made by German research vessels.

fishery research vessel "Walther Herwig" and the fishery motor vessel "Karlsburg," chartered for research purposes (October 1980) amounted to about 200 kg/30 min. trawling time. The catches were best at depths below 700 m (fishing was carried out down to a depth of 1500 m). That zone, which is frequently steep and can be fished only with difficulty, is located within the area of the relatively warm Irminger Stream component of the east Greenland Stream with water temperatures of between 4 and 5.6°C (Figure 11).

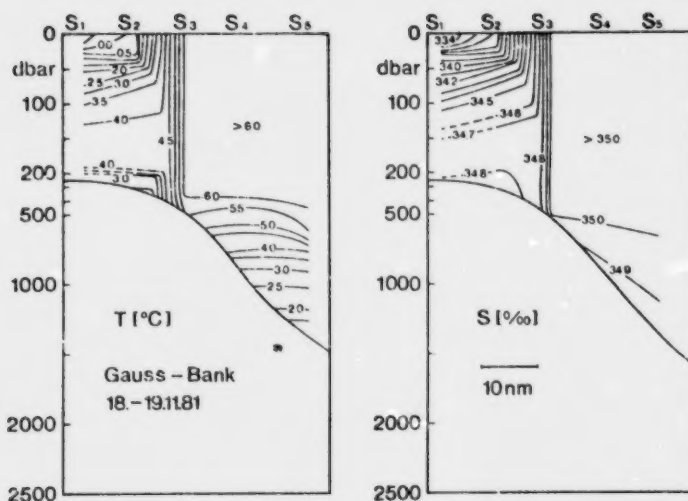


Figure 11 - Section (SE/NW) through the Gauss Bank showing temperature and salinity distributions in front of the coast of eastern Greenland (from Stein, 1982)

On the shelf down to a depth of about 500 m, we encounter colder water of the polar component of the east Greenland Stream, and there occur, in dense concentrations, roughhead grenadiers (*M. berglax*), which are taken by vessels of the Federal Republic of Germany (cf. p. 7, and Section 4.1.).

Along the Icelandic shelf slope, rock grenadiers occur, above all, off the western, southern and south-eastern coasts of the island (Figures 4 and 12). According to Pechenik and Troyanovsky (1970), the highest concentrations of this fish were found south of the Grindavik Deep, near the Beru Deep, and further south near the Lousy Bank. Favorable fishing times would be July and August off SW Iceland, and the period between September and February off Iceland including the southern slope of the Iceland-Faroes Ridge. According to Magnusson (1977), *C. rupestris* may be encountered mainly south and west of Iceland at depths between 600 and 1000 m at water temperatures between 3.2 and 6.8°C.

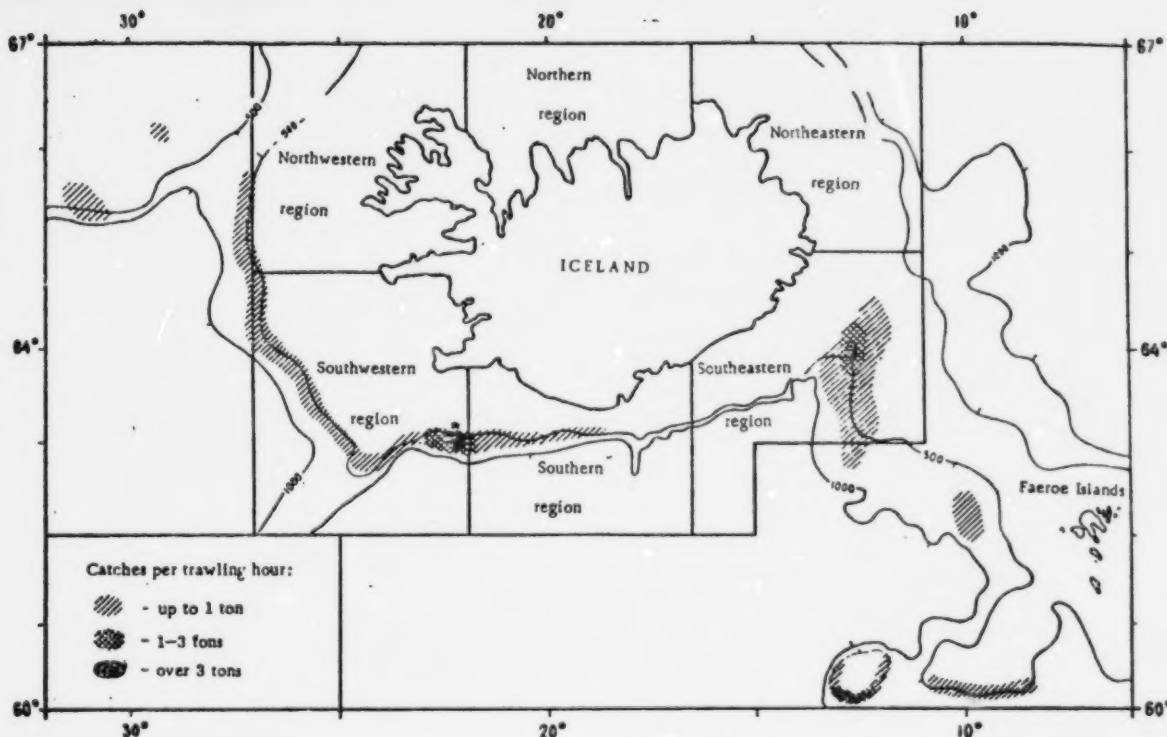


Figure 12 - Occurrence of the rock grenadier in front of Iceland according to Russian studies (from Pechenik and Troyanovsky, 1970)

The observations made during the voyages of the German research vessels are in agreement with the latter results (Figure 4). Rock grenadiers were caught west and southwest of Iceland at depths below 420 m; the fish stock density increased below 600 m; the water temperatures amounted to between 5.8 and 9.4°C. On the Iceland-Faroese Ridge, Kotthaus and Krefft (1967) found this grenadier at depths between 400 and 760 m (average: 640 m) at bottom water temperatures of between 1.1 and 4.2°C (usually, 3.5°C). Haedrich (1974) has described the catch of 49 rock grenadiers (measuring 7 to 94 cm in length) in the Strait of Denmark off western Iceland by the fishery research vessel

"Walther Herwig" in the pelagial at a depth between 1000 and 2100 m, 270 to 1440 m above the bottom of the sea, suggesting that C. rupestris will from time to time leave the bottom of the sea to feed in the free water (cf. Section 3.5.).

It appears that C. rupestris is missing off the northern side of Iceland. That fact must probably be attributed to the prevailing water temperatures (which water is of polar origin).

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In the Bear Island-Spitzbergen area, only single rock grenadiers or rock grenadiers in small numbers were taken in the German scientific catches. South of Bear Island (Figure 4), the fishing depth was between 240 and 620 m. The northern most catches consisted of single individuals west of Spitzbergen at 77°30'N to 80°N at a depth of between 364 and 487 m at temperatures between 2.2 and 2.7°C.

According to Eliassen (1983), the rock grenadier occurs along the coast of Norway and in the deeper fjords between Trondheim and the Lofoten Islands. The catches there were made using bottom trawls or in the pelagic zone up to 100 m above the bottom at depths between 350 and 707 m. The water temperatures there varied between 6.0 and 6.7°C. According to Ehrenbaum (1936), this fish species, however, occurs up to the Murman coast. In recent years, German fishery vessels have landed small quantities of grenadiers from by-catches off the coast of Norway (Table 3).

The range of the rock grenadier extends from the Norway Trough in the North Sea to the Skagerrak and the Bohuslän coast. On the fishery research vessel "Anton Dohrn," Sahrhage (1964) caught, during July, almost 300 kg/ 30 min trawling time at a depth of 320 m along the shelf slope of the Grand Fishermen Bank ("Grosse Fischerbank") near the Norway Trough at a bottom water temperature of 6.3°C (Figure 4).

The grenadier stocks of the western European continental slope and the offshore banks between the Faroe Islands and the mouth of the Biscaya have been investigated in some detail in recent years. British research vessels have found rock grenadiers widely distributed from the Faroe Islands down to the southern Porcupine Bank mainly at depths between 600 and 1000 m. The biggest catches were made between 55° and 59°N, where the catch rates amounted to between 0.7 and 1.9 t/fishing hour. The highest fish concentrations (densities) were found in a relatively narrow depth zone; in order for the enterprise to be profitable, fishing must be carried out very precisely along the depth contour lines. In that zone, water temperatures of between 7.6 and 11.5°C prevail, i.e. temperatures higher than those found in the rock grenadier ranges described previously (Bridger, 1978; Gordon, 1978). Seasonal differences in distribution and density of this fish could not be demonstrated. C. rupestris was no longer found below a depth of 1800 m (Gordon, 1979a). In the course of voyages on the French research vessel "Thalassa," during the spring, Geistdoerfer (1977) found rock grenadiers below a depth of 600 m in the Rockall area and on the Hatton Bank. On the latter, he had the best catches (0.5 t/trawling hour) at a depth of between 730 and 870 m. The bottom water temperatures amounted, in general, to between 7.2 and 8°C. Glukhov et al.(1980) have reported similarly low catch rates for the area of Outer Bailey-Bill Bailey Bank southWest of the Faroe Islands, where these workers caught maximally 0.75 t/haul at depths of between 740 and 1600 m (bottom water temperatures usually were between 6.5 and 7.7°C).

German studies of this grenadier fish have been carried out in that area since 1974 within the framework of—so far—eight "deepsea fishery" voyages on the fishery research vessel "Walther Herwig." During one of these voyages Ehrich (1953) found C. rupestris in the area of the Rockall Trough at depths

between 385 and 1875 m (maximal fishing depth). The highest density was found at depths between 700 and 900 m, as is demonstrated by the following compilation:

21

<u>Water depth</u> (m)	<u>Fish density</u> (t/Sm ²)	<u>Number</u> <u>of hauls</u>
less than 500	0 +	86
500 - 700	0,6	43
700 - 900	9,8	37
900 - 1100	5,5	31
below 1100	4,0	13

At the fishing depths yielding the greatest catch, the water temperatures measured were between 6.8 and 7.3°C.

As Ehrich has furthermore established, the zone of maximal fish density for this grenadier was located along the shelf slopes in the area of the Celtic Sea and the Biscaya at depths about 1000 m lower than in the waters further north:

<u>Water depth</u> (m)	<u>Fish density</u> (t/Sm ²)	<u>Number</u> <u>of hauls</u>
less than 700	0	78
700 - 900	0,4	8
900 - 1100	5,3	6
1100 - 1300	0,6	4

Ehrich attributed his findings to the preferred temperature of this grenadier (6 - 7.5°C) which, there in the south, was found at depths greater than in the north. Individual C. rupestris and small numbers of them (up to 25 kg/hour) were taken in the inner Biscaya and off Cape Finisterre (Figure 4).

Figure 13 provides an overview of maximal catches (kg/trawling hour) of rock grenadiers made during the "deepsea fishery" voyages of the fishery research vessel "Walther Herwig" since 1974 using the 200-foot bottom trawl (312 hauls) in the area west of Great Britain and Ireland. According to Ehrich (1984), the catches were maximal on the Tory fishing grounds north-west of Ireland (May and October), along the southern slope of the Lousy Bank (all year round), and along the northern edge of the Porcupine Bank (February). Additional data on the depth distribution of this grenadier in relation to other fish species may be found in Rätz (1984).

As has been mentioned in the Introduction, the fishery research vessel "Walther Herwig" caught, during June of 1982, individual C. rupestris on the mid-Atlantic Ridge between 47° and 52°N, 27° - 29°W (Figure 4), and this using the bottom trawl net at a depth of 1900 m as well as using the 1600-mesh floating trawl net close to the bottom at depths of 2600 and 3200, respectively (Post, 1982; and Post, personal communication). These individuals measured between 32 and 82 cm in length. We have already referred to the grenadier finds reported by Gushchin and Kukuev (1980) from that area.

3.2. Length and age compositions

Proper measuring of the total length (TL) is often associated with considerable difficulties in the case of grenadiers, because the long tails are either broken off or have regenerated in a large number of the individuals caught. For that reason, the pre-anal length has been measured

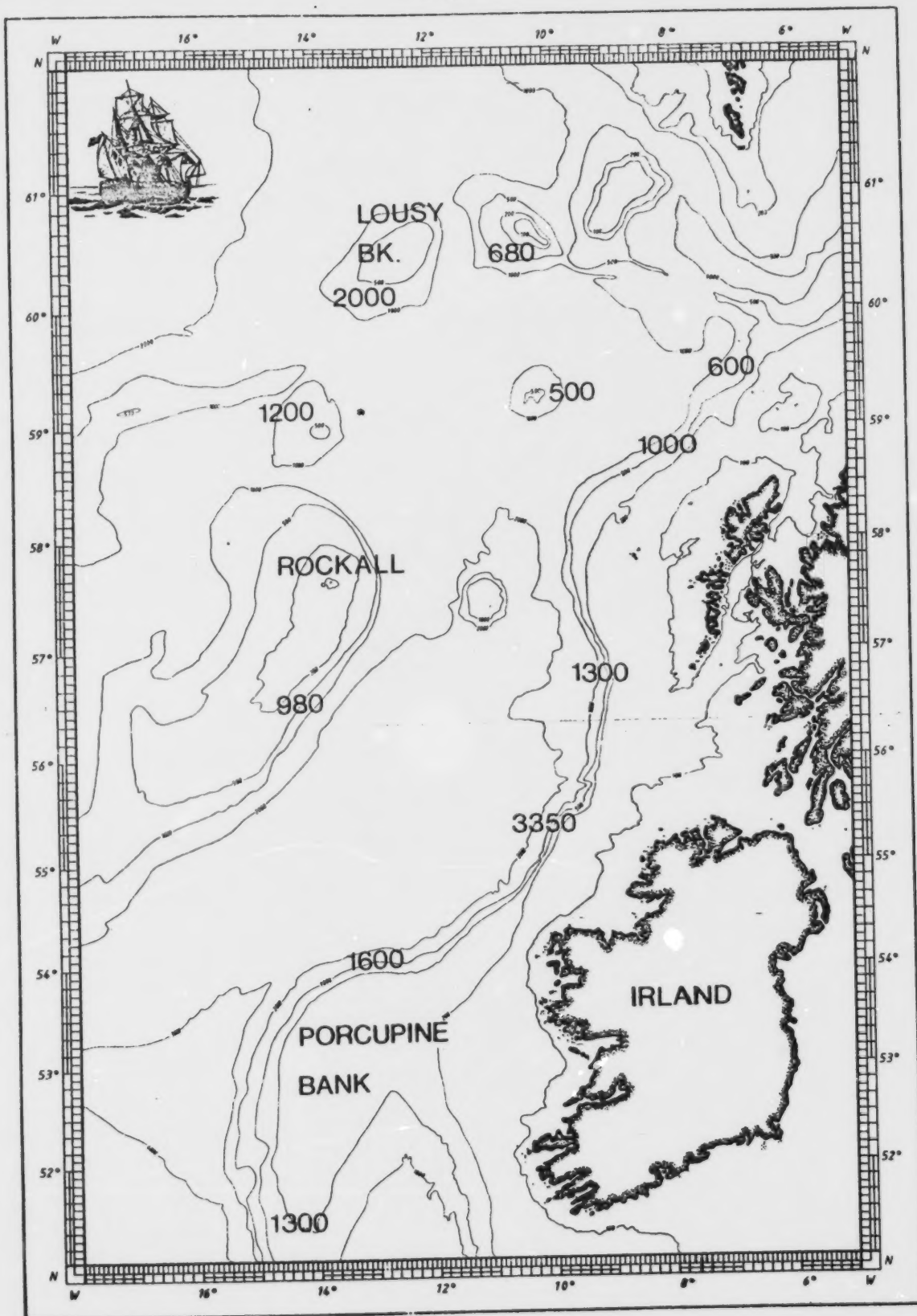


Figure 13 - Maximal catches of rock grenadier by fisheries research vessel "Walter Herwig" in the waters west of Great Britain and Ireland (in kg/trawling hour)

in many studies instead of the TL, i.e. the length from the tip of the snout to the vent (Kosswig, 1979; Messtorff and Kock, 1979; Savvatimsky, 1981). However, since the vent is frequently distorted and, in slaughtered fish of commercial catches, is usually destroyed, the "pre-anal fin length" (SAF), i.e. the length from the tip of the snout to the base of the first ray of the anal fin, is regarded as the best method for determining the length of grenadiers. That method has been proposed by Jensen (1976), and his suggestion has been supported by Parsons et al. (1978). Following a review of the different methods by Atkinson (1980), the Scientific Council of the NAFO recommended in July of 1980 that, at the international level, length measurements in C. rupestris and M. berglax be made and recorded separately according to sexes and in pre-anal fin length with an accuracy of 0.5 cm. The ICES accepted that recommendation in 1981 for investigations carried out in the eastern North Atlantic.

For investigations requiring conversion of SAF to TL and vice versa, Jensen (1976) has elaborated the following formulas for C. rupestris:

24

$$l(TL) = l(SAF) \times 3,437 + 11,378$$

$$l(SAF) = l(TL) \times 0,291 - 3,310$$

For the relation between SAF and weight (W) in C. rupestris, that author found:

$$W = 1,118 \times l(SAF)^{2,287}$$

On the basis of specimens caught by German fishery research vessels off western Greenland, Ehrich (personal communication) established the following relation between SAF and TL:

$$\begin{aligned} l(TL) &= l(SAF) \times 4,18 + 1,75 \\ l(SAF) &= l(TL) \times 0,239 - 0,419 \end{aligned}$$

For the rock grenadier in the waters west of the British Isles:

$$\begin{aligned} l(TL) &= l(SAF) \times 4,38 + 1,56 \\ l(SAF) &= l(TL) \times 0,228 - 0,356 \end{aligned}$$

Recently, Savvatimsky (1985) has voiced doubts as to whether pre-anal length (his term for SAF) actually represents a proper unit of measurement since the relation of that parameter to TL changes with increasing fish size and, in addition, differences have been established between males and females. For these reasons, the latter author regards TL as a more precise parameter.

Figure 14 illustrates the length composition of Russian grenadier catches made in different areas during the summer of 1970 (Podrazhanskaya, 1971).

The smallest specimens in the western North Atlantic were found on the northern Newfoundland Bank (modal length: 45 - 47 cm). The mean length of the fishes caught increased in the direction toward the north by way of northern Labrador and Baffin Island to western Greenland. The largest fishes were taken off Iceland. The data published by Savvatimsky (1971) on the length composition of grenadiers from the northern Newfoundland Bank reveal, from 1967 to 1970, a distinct decrease of the fish lengths observed—a finding attributed by that author to the effects of intensive fishery in that area.

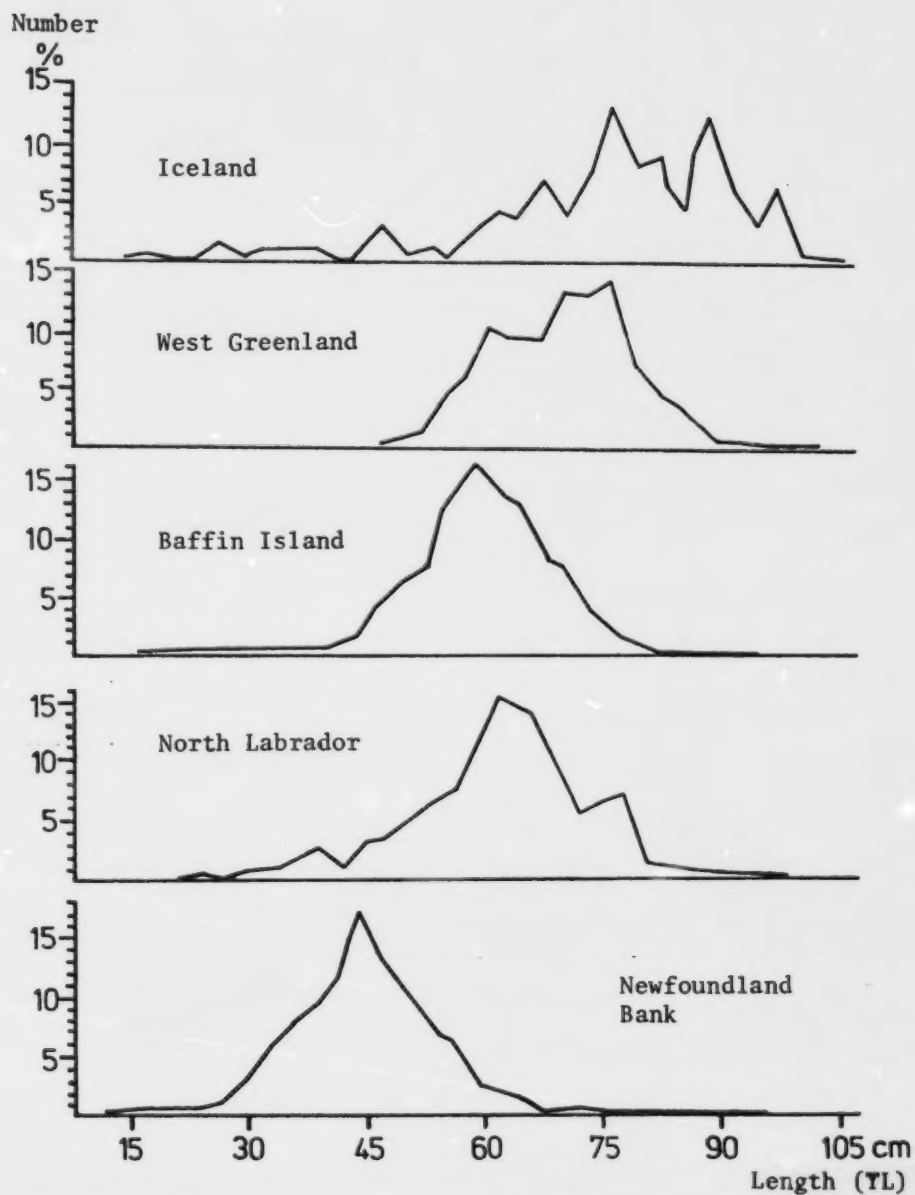


Figure 14 - Length composition of rock grenadiers in USSR catches during the summer of 1970 (after Podrazhanskaya, 1971)

On the other hand, Berth et al. (1979) found in grenadier catches made on the northern Newfoundland Bank during the fall of 1978 a length composition (with modal lengths of 60 to 66 cm) similar to that reported by Savvatimsky for 1967 (Figure 15). Off northern Labrador, the length composition was similar in 1970 and 1978, respectively; off Baffin Island, the grenadiers caught in 1978 were significantly smaller than those taken in 1970.

According to the results of length measurements made on the fishery research vessel "Walther Herwig" and fishery research vessel "Anton Dohrn" during the fall of 1979 and the fall of 1980 in ICNAF/NAFO area 2J, the size composition of the grenadiers was very similar to that reported by Berth et al. (1977) for area 2G (Figure 15, middle part). The length composition in German scientific catches off Greenland is illustrated in Figure 15a.

The data on the length composition of C. rupestris in the waters off western and southern Iceland (Figure 16) reported on a regular basis by Magnusson (1977a; 1978b; 1979; 1980; 1983) reveal—like the measurements carried out by Podrazhanskaya (1971) in the same area (Figure 14, upper part)—the presence of fishes over a wide length range between 4 and about 115 cm. During the years 1975 to 1980, the length composition was remarkably constant. On the whole, the bigger fishes measuring > 30 cm in length were found mainly at depths between 500 and 800 m, while the smaller grenadiers were encountered below 700 m, i.e. mainly between 900 and 1000 m. Small grenadiers were missing off southeastern Iceland.

According to a list of the length composition of rock grenadiers in British catches west of Scotland compiled by Bridger (1978) (Figure 17), this fish is found there in a wide spectrum of sizes ranging from 10 cm to 120 cm. The length compositions determined by Geistdoerfer (1977) on the Rockall Bank

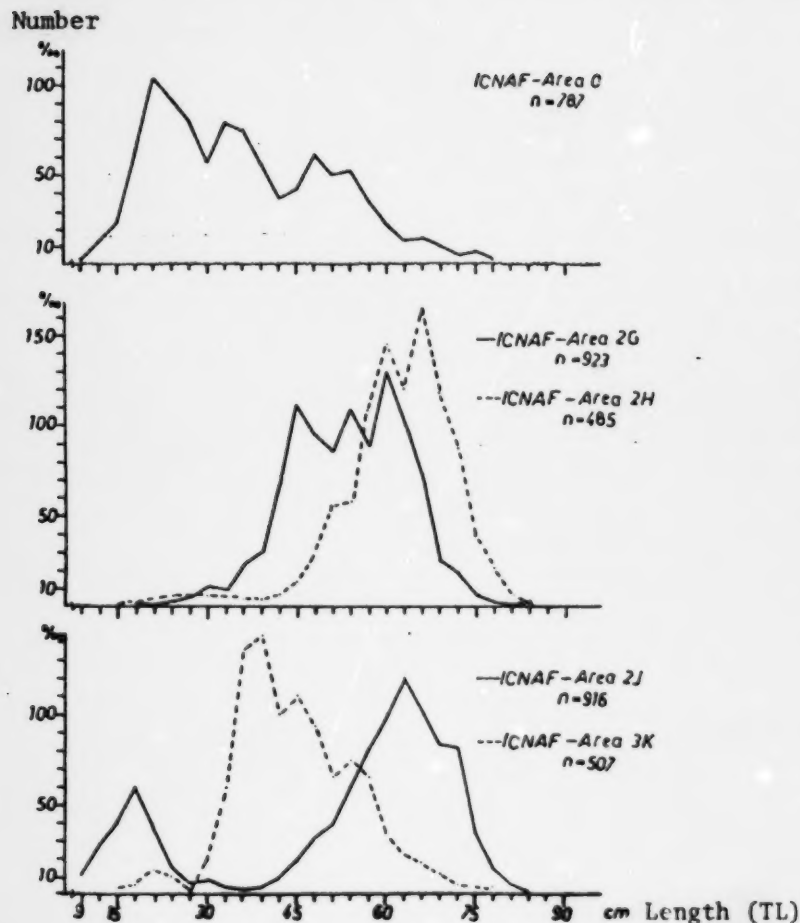


Figure 15 - Length composition of rock grenadier (from Berth et al., 1979).
Upper diagram: in front of Baffin Island; middle diagram: in front of
northern Labrador; lower diagram: north of Newfoundland Bank

and the Hatton Bank were very similar, and German measurements from the Rockall Trough area (Ehrlich, 1983) have revealed the same pattern. Due to the different growth rates exhibited by males and females, the length distribution curves of the two sexes differ, with higher recorded values for the females (Figure 18).

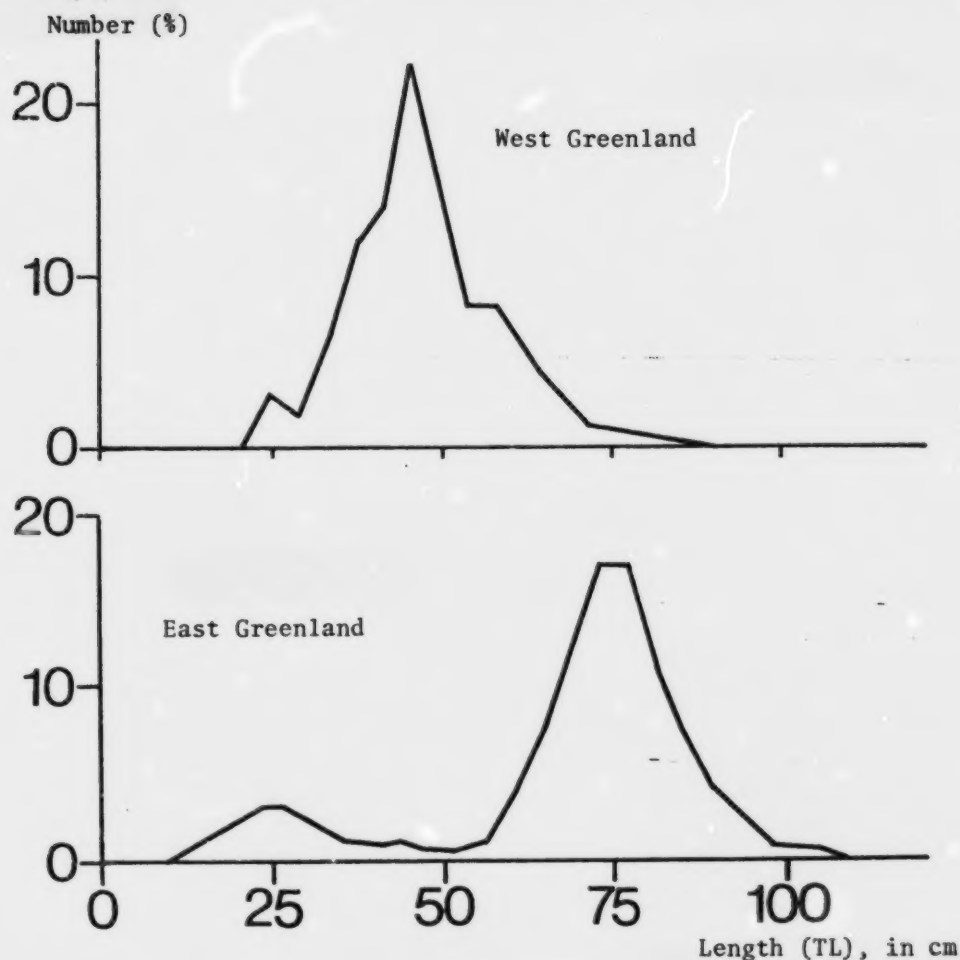


Figure 15a - Length composition of rock grenadier in research catches made by fisheries research vessel "Anton Dohrn" in front of western Greenland (May 1980, $n = 421$) and by fisheries motor vessel "Karlsburg" in front of eastern Greenland (September - October 1980, $n = 2074$)

Considerable differences in length composition of grenadier catches may be found at different depth levels in the same sea area. According to Gordon (1979), the small grenadiers are found mainly at depths around 1000 m along the continental shelf west of the Hebrides (Figure 19). It appears that they are distributed deeper with increasing body size. The biggest

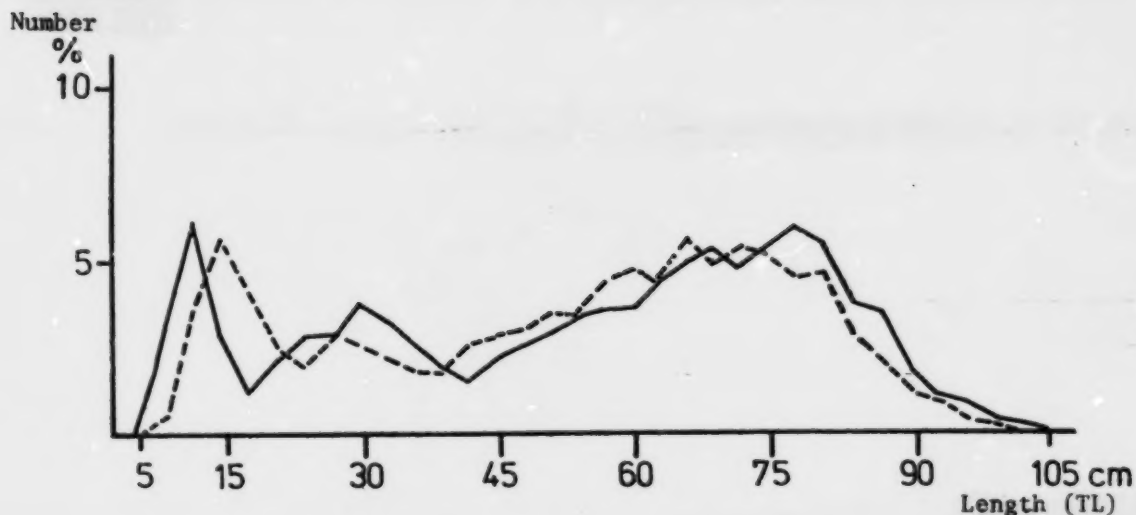


Figure 16 - Length composition of rock grenadier in catches off Iceland (after Magnusson, 1977a; 1978a). Continuous line: 1975 ($\underline{n}$ = 3416); broken line: 1976 ($\underline{n}$ = 9150).

grenadiers were caught mainly between 667 m and 1273 m. During the period between March and November, that distribution appeared to be constant. Ehrich (1983), too, found increasing shares of juvenile grenadiers with increasing water depth, and that finding is in agreement with observations made by Magnusson off Iceland, which have already been mentioned further above.

The age determination of grenadiers is associated with considerable difficulties. Due to the slow growth of this fish (cf. Section 3.3.), a given stock consists of many year classes, and the zones forming the annular rings in otoliths and scales are close together.

According to Savvatimsky (1971; 1972), the otoliths turned out to be useless for determination of age using standard methods; however, it was possible to visualize the zones of the rings better by preparing transverse

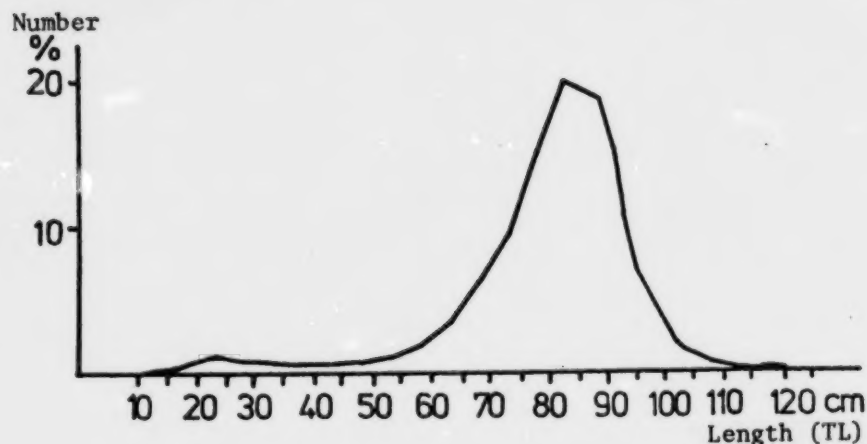


Figure 17 - Length composition of rock grenadier in the waters west of the British Isles (after Bridges, 1978); $n = 47,785$.

otolith sections, decalcifying the material, and staining with hematoxylin. Koch (1976) placed the otoliths into 4% Formalin[®] and dipped them in water in hydrochloric acid before examining them under/transmitted light. Using that procedure, age determination is possible in specimens measuring up to about 40 cm in length. Gordon (1979) was able to read almost 80 per cent of the otoliths examined by him in specimens measuring up to 30 cm in length; he did that under terpeneol in a black dish under incident light. The standard technique used in broken otoliths was successful in small grenadiers from the area west of Scotland; scorching of the fracture surface improved readability.

Certain investigations have demonstrated that the scales are better suited than otoliths for determining age in grenadiers, and that this is the only promising method in bigger specimens. Savvatimsky (1972) and Savvatimsky et al. (1978) have investigated scales in polarized light. Kosswig (1974; 1980), in his investigations, has used scales impregnated with 1.5%

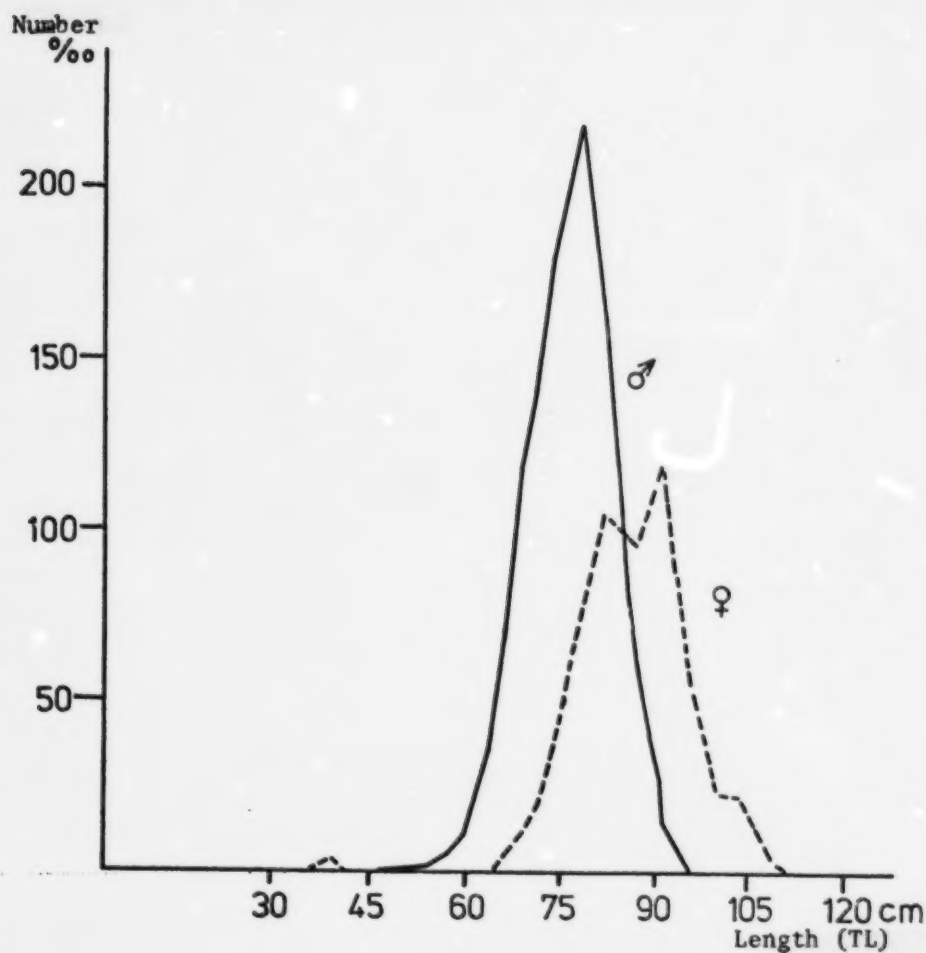


Figure 18 - Length composition of rock grenadier in the Rockall Trench, listed according to sex (after Ehrich, 1983)

silver nitrate solution, and then examined them under polarized light. That method, which has been adopted also by Eliassen and Magnusson, should provide the best results.

Figure 20 illustrates the age composition of grenadier catches made in a number of different areas. On the northern Newfoundland Bank (A) the catches consisted in 1969 of specimens of many year classes between three

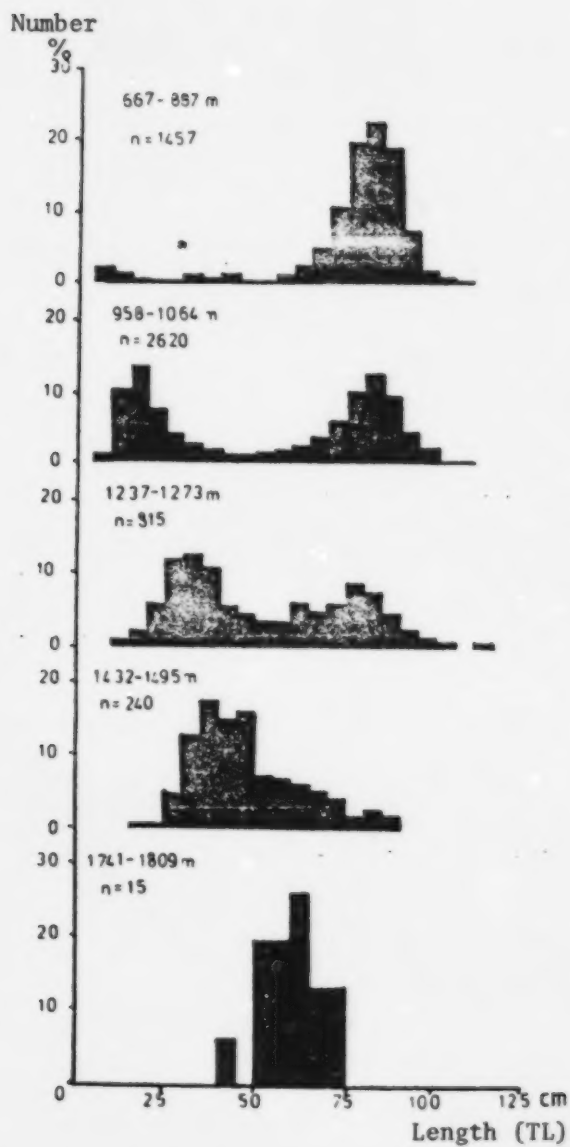
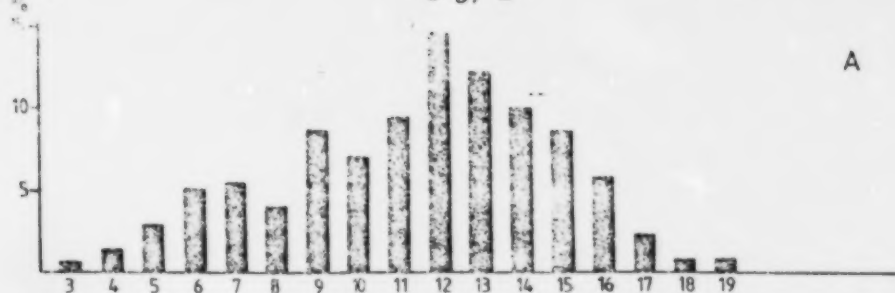


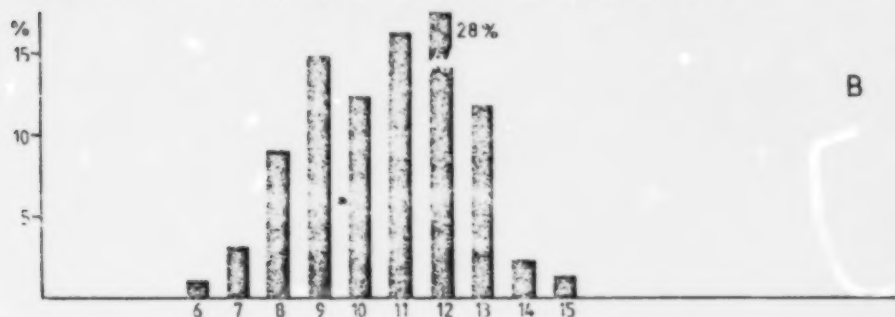
Figure 19 - Length composition of rock grenadier in the waters west of Scotland at various depths (after Gordon)

Number

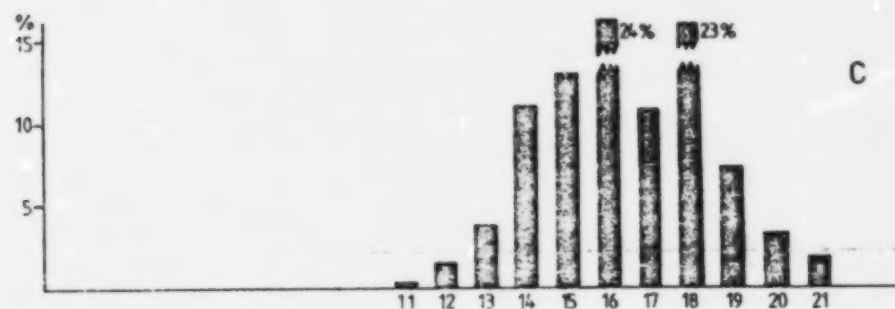
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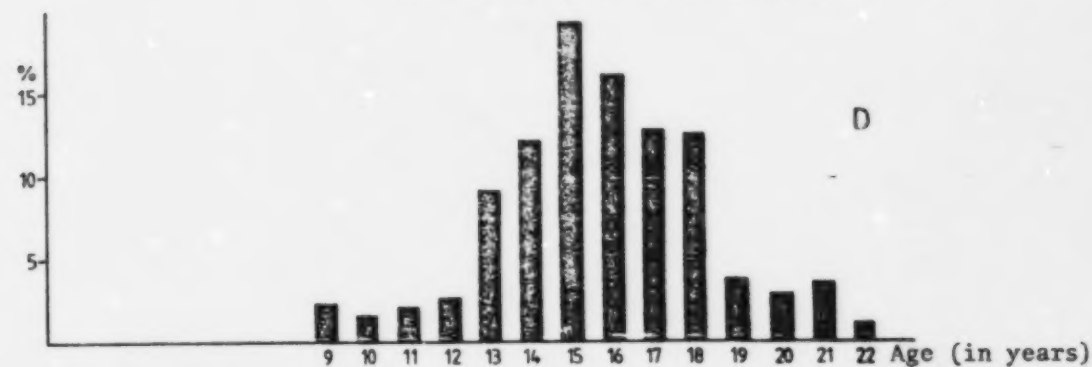
A



B



C



D

Figure 20 - Age composition (in %) in catches of rock grenadier.

A: northern Newfoundland Bank, 1969, $\bar{n} = 277$ (after Savvatimsky, 1972)

B: western Greenland, 1979, $\bar{n} = 290$ (after Kosswig, 1980)

C: west of the British Isles, south of the Faroe Islands, 1979, $\bar{n} = 382$ (after Kosswig, 1981)

D: the same area as under C, 1981 (after Kosswig, 1984)

and 19 years (Savvatimsky, 1972). A compilation prepared by Atkinson (1981) indicates that the age composition in the years 1972 to 1978 in NAFO sub-areas 2 and 3 showed a distribution similar to an overall range of 3 to 23 years and a main share of specimens between 9 and 20 years. Off western Greenland (B), Kosswig's (1980) investigations revealed a more narrow range of age groups with specimens aged between 6 and 15 years. In the waters west of the British Isles and the southern Faroe Islands (C and D, respectively), Kosswig (1981; 1983; 1984) found, on the other hand, a considerably different age distribution with a preponderance of older individuals up to an age of 22 years, and absence of grenadiers < 9 years. Compared to the above results, the values determined by Bridger (1978) in otoliths—indicating ages of up to 40 years and higher in grenadiers taken in the same region—appear to be rather high and should be verified.

3.3. Growth

The length-weight ratio of rock grenadiers is illustrated in Figure 21. These data demonstrate that the fishes taken off Iceland, at identical length, are considerably heavier than the grenadiers caught in the region around Newfoundland, Labrador and Baffin Island. On average, the males weigh less than the females of the same length, and, with increasing size, exhibit weight gain that is relatively slower than that seen in the females. For the grenadiers of NAFO subareas 0 - 3, Atkinson (1980a), on the basis of further data, has calculated a curve similar to the one presented as Figure 21, using the formula:

$$W = 0.0068 TL^{2.7251}$$

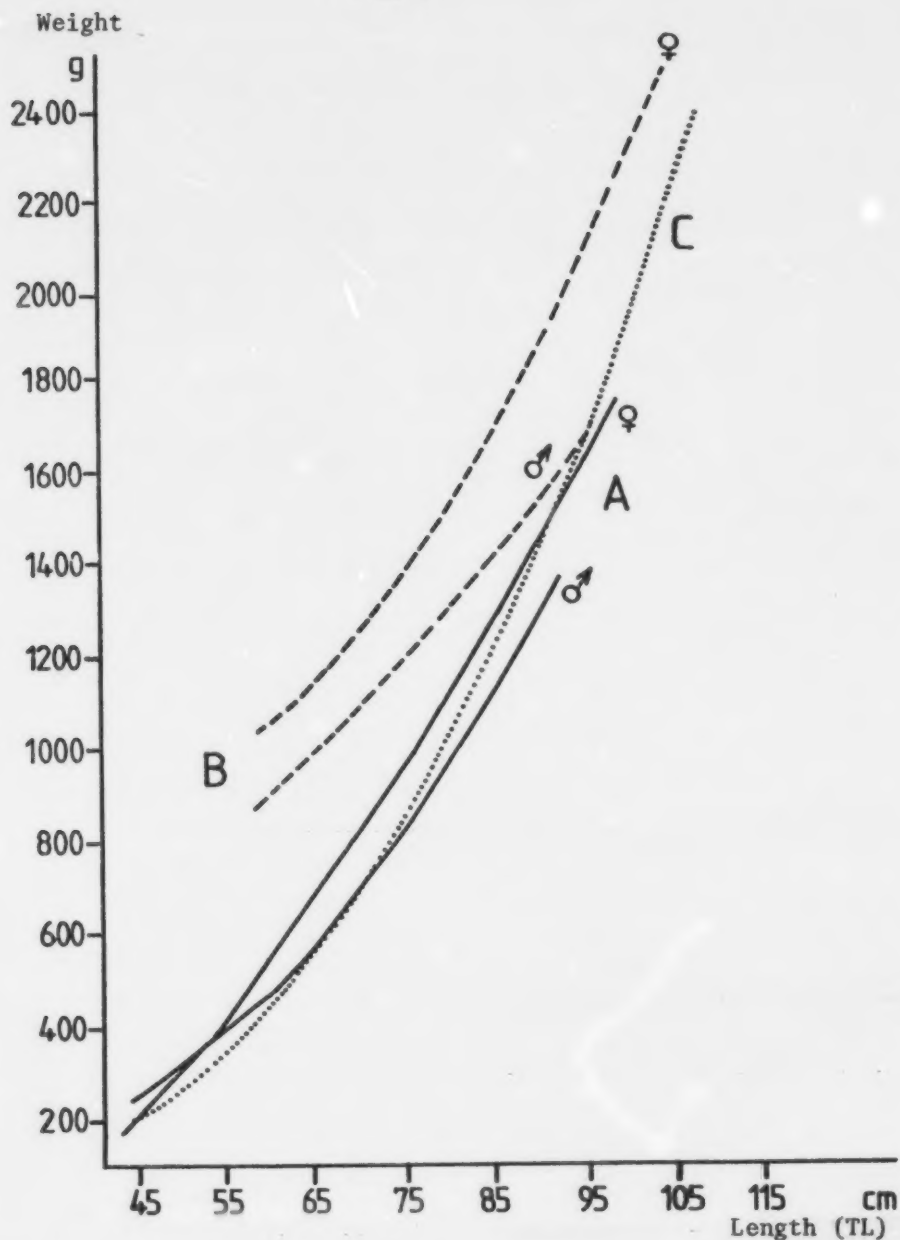


Figure 21 - Length/weight relation in rock grenadier.

- A: Newfoundland, Labrador, Baffin Island (after Savvatimsky, 1969)
 - - - B: Iceland (after Savvatimsky, 1969)
 (The equations presented by Savvatimsky for length/weight relations have not been used here, since they do not correspond to the trend of the curve)
 C: Waters west of Scotland (after Gordon, 1979)
 ♂ and ♀: $W = 0.00491 L^{2.7979}$

for the two sexes together. The grenadiers from the waters west of Scotland exhibit—up to a length of about 100 cm—a length-weight ratio similar to that found in specimens from the western North Atlantic.

In the representation of the relation between length and age, it becomes apparent that the rock grenadiers from the northern Newfoundland Bank, exhibiting a length of 60 cm, are about ten years old and, exhibiting a length of 100 cm, are about 25 years old (Figure 22). Grenadiers of similar ages from Iceland and from the waters west of Scotland, respectively, are considerably smaller, i.e. they grow even more slowly than do the grenadiers from the western North Atlantic.

Data on the relation between weight and age have hitherto been published for this grenadier only to a small extent (Figure 23). Investigations dealing with that aspect in the ^{entire} area of the eastern North Atlantic would be very desirable in order to improve the base for calculations of population dynamics.

On the whole, it is evident that the rock grenadier is a slow-growing fish with long natural life.

3.4. Reproduction

Relatively little is as yet known regarding the reproductive biology of this grenadier. That is true also with respect to the distribution of eggs, larvae, and juveniles.

According to data provided by Gordon (1978), the ovaries of grenadiers measuring between 75 and 105 cm in length (a total of 21 individuals was examined) contained, on average, 32,364 eggs (10,762 to 63,358 eggs). These values are in agreement with the results reported by Marshall (1965), who determined fecundity to amount to about 25,000 eggs.

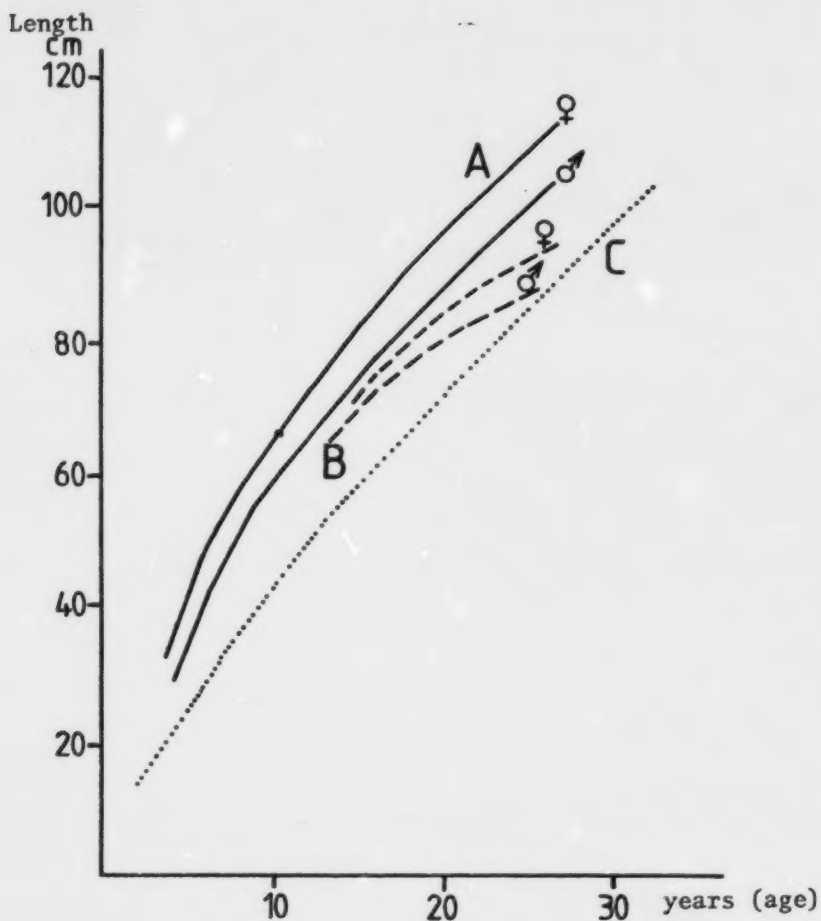


Figure 22 - Length/age relations in rock grenadier.

- A: northern Newfoundland Bank (after Savvatimsky, 1971)
 σ : TL = 14.896, $\text{age}^{0.59}$. φ : TL = 17.2, $\text{age}^{0.57}$
 - - - B: Iceland (after Savvatimsky, 1971)
 C: waters west of Scotland (after Gordon, 1979)

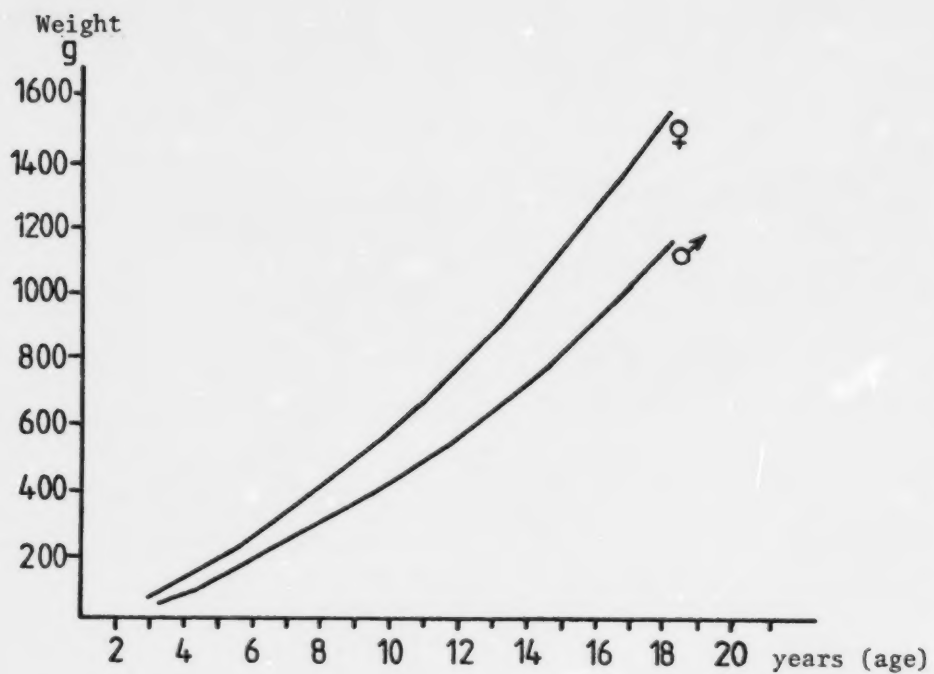


Figure 23 - Weight/age relations in rock grenadier from the northern Newfoundland Bank (after Savvatimsky, 1971)

♂ : $W = 8.77, \text{age}^{1.66}$

♀ : $W = 13.8, \text{age}^{1.6}$

It has been suggested that the eggs, which have a diameter of 1.8 to 2.4 mm and contain a fat droplet (Grigorev and Serebryakov, 1981), are released close to the bottom (at bathypelagical levels), and then rise in the water. During April and May of 1976, Merret (1978) found in the waters west of Great Britain larvae exhibiting a standard length of between 8 and 43 mm at a depth of 500 - 25 m. According to that author, juvenile stages exhibiting a standard length of between 61 and 106 mm were caught there also using the RMT 8 (pelagic) at a depth of 700 to 900 m, and this about 70 seamiles off the continental slope, where the adult grenadiers occur. Marshall (1965; 1973) has mentioned the catch of advanced post-larvae in the Sea of Norway during June and July. Magnusson's (1977a; 1978a) data indicate that off Iceland, from the west to the southeast, juvenile grenadiers with a length of 4 cm and up are encountered in scientific catches (cf, Figure 16). Haedrich (1974) has described the catch of grenadiers with a length of 7 cm and up using a pelagic trawl on the fishery research vessel "Walther Herwig" in the Strait of Denmark at depths between 760 and 2000 m. Finally, according to Grigorev (1972), juvenile grenadiers measuring about 8 cm in length occur in the waters of the Newfoundland Bank, off the Cumberland Peninsula and on to western Greenland and southwestern Iceland. This sparse knowledge regarding the distribution of the juvenile stages provides some evidence regarding the spawning areas of this fish, if we assume that no drifting of the brood takes place over wide spaces.

From observations made in adult grenadiers ready to spawn and spawning grenadiers, it has been concluded that spawning may well take place the year round, or, at least, take place over a large part of the year (Grigorev, 1972; Magnusson, 1977). Individuals in greatly different stages of maturation may frequently be found simultaneously in catches. Histological studies

carried out by Gordon (1979) have demonstrated that the males appear to be able to fertilize the eggs between March and November. The eggs present in the ovaries are all of the same size, and there is no evidence suggesting that spawning in batches takes place. However, numerous findings indicate that there are two main periods for spawning, i.e. a relatively short one during the spring (April - May), and a longer one during the fall (September - October) (Marshall, 1965; Geistdoerfer, 1977; 1979).

In the western North Atlantic, the predominant part of the grenadier catches consists of juvenile individuals as yet not sexually mature. Spawning probably takes place mainly at depths below 1000 m, where so far only little fishing has been carried out (Grigorev, 1972; Savvatimsky, 1972). That conclusion is supported by findings obtained by Savvatimsky (1972) and Parsons (1975) showing that the numbers of mature or maturing grenadiers increase with increasing water depth. Large mature individuals were caught off Central Labrador, for example, at a depth of between 1470 and 1520 m. According to Savvatimsky (1972), grenadiers were encountered during May of 1970 off Nova Scotia at a depth of between 850 and 1270 m. The number of individuals close to spawning increased with increasing depth of the water. In ICNAF area 2J, Geistdoerfer (1979) observed during July of 1975 in catches made at a depth of 720 - 940 m that the adult individuals were in the stage of gonadal regeneration. These results demonstrate that spawning took (takes) place during the spring.

Predominantly juvenile grenadiers are caught also off Iceland, from the west to the southeast, while all sizes, from brood to very large individuals, occur north of the Reykjanes Ridge (Magnusson, 1977). Spawning grenadiers were observed only in small numbers. The coexistence of individuals in greatly different stages of maturation suggests that this fish has an extended

spawning period. Off Iceland, Pechenik and Troyanovsky (1970) found an increase of mature females during July, while the females were mostly spent during November, i.e. spawning took place during the fall. According to Podrazhanskaya (1971), spawning starts off southeastern Iceland during May, and the grenadiers are spent by August. There, as well as in other areas, it has been observed that gonadal maturation shows a tendency to occur earlier in the females than in the males (cf. also Geistdoerfer, 1977; 1979). Grigorev and Serebryakov (1981) found, during September, grenadier females ready to spawn (pelagic) at a fishing depth of 750 - 800 m near the Reykjanes Ridge. According to Marshall (1973), mature eggs [eggs ready to be fertilized] may be found in grenadier females during October off the coast of Norway.

Two spawning periods have been established to occur also in the waters west of the British Isles. Savvatimsky (1969) has observed spawning males and females just spent around the end of October 1968 northwest of the Rockall Bank (at a depth of 580 to 850 m). Females ready to spawn and spent females mostly measuring between 70 and 90 cm in length were caught together during the middle of September 1973 along the northwest slope of the Hatton Bank at a depth of about 1200 m (Bridger, 1978). Geistdoerfer (1977; 1979), on the other hand, found during April and May of 1975 and during these months in 1976 grenadiers ready to spawn and spawning grenadiers together on the Rockall Bank. By the end of May, 78 per cent of the females caught were spent. During those two years, it appears that spawning occurred somewhat later on the Hatton Bank; toward the end of May, 44 per cent of the females taken were just spent. On average, the gonads of the males, with respect to maturation, were somewhat behind those of the females. German observations (Kock, personal communication) have shown that, during January of 1983, most

grenadiers on the Rockall Bank exhibited gonads in Stages III and IV of maturation, with individual females being about ready to spawn (Stage V). However, among the grenadiers caught during August of 1981 and August of 1982 along the south-eastern edge of the Rockall Bank at a depth of 700 m, there were numerous females just about ready to spawn (Stage V; the eggs, in part, were transparent as glass).

These observations are in agreement with those reported by Gordon (1979), who found a peak in spawning activities during the fall off the west coast of Scotland; in addition, however, he found between March and November females in all stages of maturation as well as mature males.

Rather noteworthy differences have been established in the different areas of the North Atlantic with respect to the shares of males and females in the catches. In the western North Atlantic, the males almost always predominate, frequently at a ratio of 2:1 (Savvatimsky, 1969; Podrazhanskaya, 1971; Geistdierfer, 1979). Similar findings have been obtained off eastern Greenland (Magnusson, 1978). In the waters around Iceland, from the northwest by the way of the southwest to the southeast, on the other hand, females were found far more frequently in the catches than males; in some instances, the share of the females amounted to 80 to 90 per cent (Savvatimsky, 1969; Grigorev, 1972; Magnusson, 1977a; 1978b; 1979). West of the British Isles, the ratio, on average, is nearly balanced (Savvatimsky, 1969) with a slight preponderance of males (50 - 60 per cent) according to Geistdoerfer (1977; 1979). However, the data on the occurrences at different depths are not in agreement. Geistdoerfer (1979) observed, on the Rockall Bank during April 1975, an increase of the share of males from 22 per cent at a depth of 714 m to 85 per cent at a depth of 950 m. Gordon (1978), on the other hand, found in investigations carried out on RRS "Challenger" in 1975 to 1977 in the

waters west of Scotland that the males occur mainly in the upper zones of the continental slope, and the females in the lower zones (decrease of the share of males from about 87 per cent at a depth of 667 - 887 m to 16 - 28 per cent at depths below 1237 m).

According to Gordon (1978), the females in the afore-mentioned area become sexually mature once they reach a length of about 50 cm. Glukhov et al. (1980), on the other hand, have reported for the area of the Faroe Islands waters west of the British Isles that sexual maturity sets in once the females measure between 81 and 86 cm in length, and the males measure between 72 and 77 cm in length.

Since only very few sexually mature grenadiers were observed in the Soviet investigations in the western North Atlantic waters, ^{from 1965-1970} and no spawning grounds could be identified, on the other hand, however, large numbers of fully grown individuals were present off Iceland, Zakharov and Mokuau (1970) concluded that spawning takes place off Iceland. That assumption, which has been supported by Podrazhanskaya (1971), is based on the suggestion that both the eggs released off Iceland and the larvae drift passively with the Irminger Stream to southern Greenland and then with the West Greenland Stream further to the waters off Baffin Island. From there, the small fish might be transported with the Labrador Stream further to the south down to the Newfoundland Bank. If that were the case, the more grown fish would have to return to the sea off Iceland for spawning. Unfortunately, it is not possible to follow the migrations of a fish living at these great depths by means of marking experiments. This particular migration theory has been rejected by Grigorev (1972), Savvatimsky (1972), Parsons (1975), and Geistdoerfer (1979), who quite rightly have pointed out that this grenadier, due to its peculiar body shape, is a relatively poor swimmer. Marshall (1965), too, has described

this grenadier as a poor swimmer, which probably does not migrate more than 100 seamiles across the continental slope. Observations made by Grigorev (1972) demonstrate furthermore that juvenile grenadiers measuring about 8 cm in length occurred along the entire coast of Canada from Baffin Island to the Newfoundland Bank. Savvatimsky (1972) and Parsons (1975) found that the share of sexually mature and maturing grenadiers increases in the ^{western} North Atlantic with increasing depth of the water, so that we must assume that spawning there takes place mainly at relatively great depths as yet not accessible to fishery (cf. also Zilanov et al., 1970). For these reasons, the four authors just mentioned have assumed that separate stocks of grenadiers exist in the western North Atlantic and the eastern North Atlantic, and we must concur in that view. However, there can be little doubt that the aforementioned currents bring about considerable drifting of both eggs and larval stages. We must hope that the unresolved questions regarding stock identification and stock separation in this grenadier will be elucidated by means of investigations of morphometric and meristic features (Savvatimsky, 1982) and through biochemical studies using electrophoretic methods (Nefyodov et al., 1976; Dushchenko, 1980).

3.5. Food

Investigations dealing with the stomach contents of the rock grenadier have demonstrated that this fish feeds chiefly on bathypelagic organisms—mainly crustaceans—while the inhabitants of the benthos represent only a small fraction of its diet. The composition of the food ingested varies greatly depending on both the area and the season.

In 1967 off Iceland, Podrazhanskaya (1968) found that 37 per cent of the specimens examined had everted empty stomachs. In the remaining specimens,

74 per cent of the stomachs contained shrimps of the family Pasiphaeidae, nine per cent Euphausiacea, four per cent Themisto sp., three per cent Calanus sp., and 2.5 per cent partly digested fishes. The share of benthic organisms (Mollusca, helminths, ophiuroids) and that of sand and mud of the bottom of the sea, on the other hand, were small. Similar results—to be sure, with varying shares of the different fractions among the pelagic crustaceans—have been obtained also in Soviet studies undertaken in other areas of the ocean (Savvatimsky, 1969; Konstantinov and Podrazhanskaya, 1972). Large grenadiers feed to an increasing extent on fishes, among them, above all, Iniomi and alepocephalids, but also anchovies, cod, redfish, catfish and other forms. In the grenadiers measuring > 100 cm in length taken from the deep zones of the Reykjanes Ridge and the mid-Atlantic Ridge, between 52 and 67 per cent of the weight of the stomach contents consisted, according to Gushchin and Podrazhanskaya (1984), of bathypelagic fishes. Glukhov et al. (1980) found in the stomachs of grenadiers caught near the Faroe Islands "shrimps," cephalopods, and bathypelagic fishes. In the grenadiers from the Rockall Bank and the Hatton Bank examined by Geistdoerfer (1976; 1979a), 20 per cent of the stomachs were empty; the contents of the stomachs of the remaining fish exhibited the following composition (frequency of occurrence):

Natantia	18%
Copepods	38%
Euphausiacea	13% (in particular, <u>Meganyctiphanes norvegica</u>)
Cephalopods	8%
Amphipods	7%
Fishes	5% (in particular, Alepocephalidae and Myctophidae as well as small rock grenadiers)

The availability of bathypelagic food influences the daily vertical migrations of the grenadier, which ascends temporarily into higher zones in order to forage.

The feeding activities appear to show seasonal variations. According to Podrazhanskaya (1968; 1969; 1971) and Gushchin and Podrazhanskaya (1984), the degree of stomach filling in grenadiers on the North Atlantic continental slopes increases from the spring to the fall (main feeding period: September - November), in order to decrease again. On the other hand, the quantities of food found in the stomachs of grenadiers in the thalassobathyal of the mid-Atlantic Ridge decrease from March to July - August, increase then up into the fall, and decrease again during the winter. Corresponding changes have been observed in both liver weight and fat content of the fish (Podrazhanskaya, 1971).

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Merret (1978) found, in the stomachs of grenadier larvae, copepods, that is mainly Calanus dinmarchicus.

Grenadiers, in turn, are preyed upon mainly by Greenland halibut (Reinhardtius hippoglossoides), which halibut frequently occurs at the same sites as the grenadier, and in fishery directed toward the grenadier, the Greenland halibut represents the greatest fraction of the by-catch (occasionally, up to 30 per cent) (Savvatimsky, 1977). In particular, off Labrador and Baffin Island, it has been observed that the stomachs of Greenland halibut were filled with rock grenadiers. Other predators of the grenadier, according to Gushchin and Podrazhanskaya (1984), are certain squalids (Etmopterus spinax, Centroscyllium fabricii), wolffishes (Anarhichas denticulatus), Aphanopus carbo, and deepsea angler (Ceratias holboelli).

3.6. Parasites

An ecological and faunistic overview of the parasitic fauna in commercial grenadier species may be found in Zubchenko'e (1981) work, which also contains a detailed bibliography of earlier publications dealing with this theme.

The rock grenadier of the western North Atlantic has been found to harbor 18 species of parasites (Table 4). Myxosporididia and Trematoda were represented most frequently with five species each. Infestations with Myxidium melanostigmum and Auerbachia pulchra were encountered most frequently. The spectrum of parasitic infestation corresponds to the diet of this fish, which dwell in the depth and feed on benthos, but, above all, forage for food also in the bathypelagic zone. According to Bakay and Zubchenko (1984), C. rupestris caught in the eastern North Atlantic on Outer Baileys and Bill Baileys Bank as well as on the Reykjanes Ridge contained a total of 16 species of parasites corresponding largely to the species listed in Table 4. Rates of infestation were highest in the case of Nematoda—in particular, Anisakis species (58%)—and that of Myxosporidia.

3.7. Stock size and utilization

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The rock grenadier grows relatively slowly and—as far as is known—does not undertake long migrations. For these reasons, a distinct effect on the stock with decreasing hourly catches and changes in length composition of this grenadier in the catches became evident already soon after commercial fishing of this fish had been commenced by Soviet Russian fishery, due to taking of the large individuals and, in particular, of the females (Savvatimsky, 1971; 1977).

Stock estimates for the rock grenadier in the western North Atlantic have been undertaken by Pinhorn (1974), Parsons (1976a), Parsons et al. (1978), Borrmann (1976; 1977; 1978), Savvatimsky and Shafran (1981) as well as by Atkinson (1979; 1980b; 1981; 1982; 1984).

For the grenadiers in the area off Labrador and Newfoundland (ICNAF/NAFO subareas 2 and 3), Pinhorn, on the basis of a cohort analysis with natural

Table 4 - Parasitic fauna found in rock grenadier. Numbers and percentages of infested fishes. N = number of fishes examined (after Zubchenko, 1981)

<u>Parasites</u>	<u>Davis Strait</u>		<u>Labrador</u>		<u>Northern New- foundland Bank</u>	
	<u>N = 105</u>		<u>N = 105</u>		<u>N = 90</u>	
	No	%	No	%	No	%
1. Myxidium melanostigmum	38	<u>36.2</u>	37	<u>35.2</u>	37	<u>41.1</u>
2. Myxidium melanocetum	-	-	4	3.8	17	18.9
3. Myxidium profundum	16	15.2	14	13.3	16	17.8
4. Auerbachia pulchra	91	<u>86.7</u>	49	<u>46.7</u>	46	<u>51.1</u>
5. Zschokkella hildae	-	-	1	1.0	-	-
6. Diclidophora macruri	15	14.3	28	<u>26.7</u>	1	1.1
7. Philobytes atlanticus	34	<u>32.4</u>	25	<u>23.8</u>	18	<u>20.0</u>
8. Scolex pleuronectis l.	7	6.6	2	1.9	-	-
9. Pseudophyllidea gen.sp.1.	3	2.9	-	-	-	-
10. Aporocotyle simplex	-	-	3	2.9	-	-
11. Glomerocirrus macrouri	8	7.6	9	8.6	12	13.3
12. Derogenes varicus	-	-	1	1.0	-	-
13. Gonocerca macrouri	13	12.4	21	<u>20.0</u>	24	<u>26.7</u>
14. Gonocerca macroformis	-	-	1	1.0	-	-
15. Contracaecum aduncum	1	1.0	-	-	-	-
Contracaecum aduncum l.	1	1.0	4	3.8	3	3.3
16. Anisakis sp.1.	1	1.0	16	15.2	3	3.3
17. Chondracanthus radiatus	-	-	1	1.0	-	-
18. Clovella adunca	-	-	9	8.6	3	3.3

mortality rates of $M = 0.2$ and $M = 0.3$, calculated a maximum sustained yield (MSY) of 22,000 to 38,000 t/year. He pointed out that fishery apparently utilized almost exclusively juvenile grenadiers, and that the potential might be higher than the latter figures if fishery could be extended to greater depths. In his calculations, based on various assumptions regarding the extent of natural and fishery-associated mortality, Borrmann arrived at a value of between 26,000 and 37,000 tons; Parsons et al., at one of about 32,000 tons; and Atkinson, at one of between 27,500 and 30,000 tons [/year].

The catches of commercial fisheries in ICNAF/NAFO subareas 2 and 3— which up to 1982 were brought ashore mainly by vessels of the U.S.S.R.— varied, during the years 1967 to 1978, between 12,000 and 31,000 tons; > 75,000 tons were taken only during one year (viz. 1971) (cf. Table 1). On average, we then arrive at a catch of 26,200 tons/year. On the basis of the above-mentioned population-dynamical calculations, it was assumed that the stock was more or less fully utilized, and, beginning in 1974, the ICNAF introduced a TAC of 32,000 t/year. During the years 1977 to 1979, the TAC was temporarily increased to 35,000 tons; in 1980, however, again reduced to 30,000 tons; subsequently, it was reduced to 27,000 tons, and finally (1983 - 1985) to 11,000 tons [/year].

Beginning in 1979, the grenadier catches in these areas dropped suddenly to between 2000 and 7000 tons/year, and stabilized at around 4000 tons beginning in 1982. The share of Soviet Russian catches decreased, and the share of the German Democratic Republic increased. These decreases of the catches were, in part, due to a reduction of the fishing effort; however, on the whole, the catch rates have gone down since 1970 (Figure 24).

This drop of catches and reduction of fishing effort in directed grenadier fishery have been associated by Chumakov and Savvatimsky (1984) with

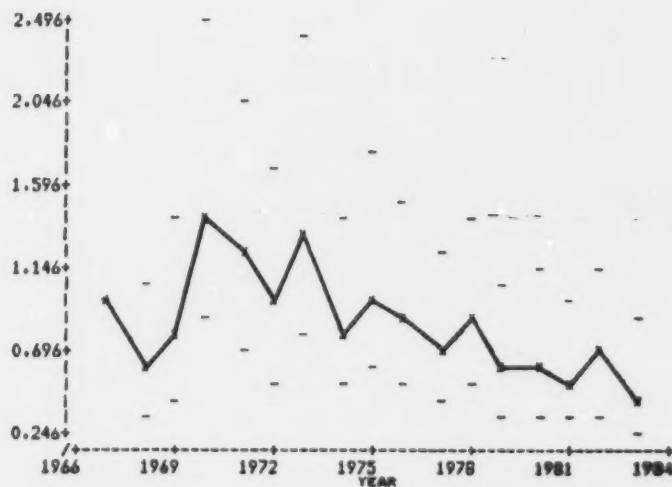
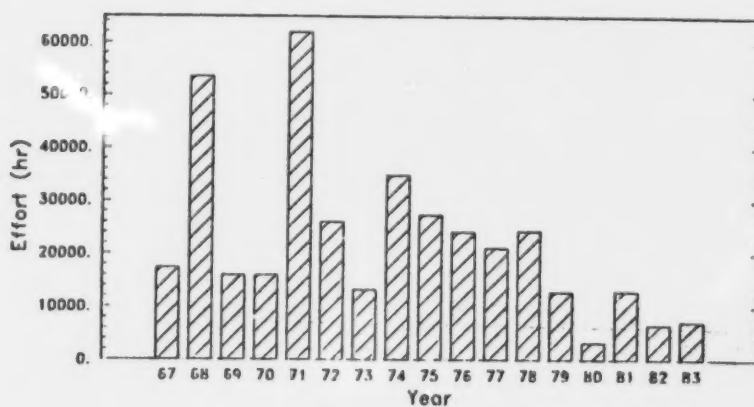
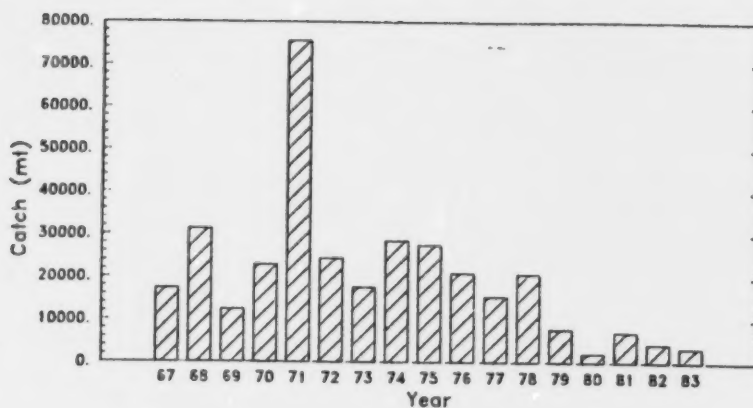


Figure 24 - Grenadier catches in ICNAF/NAFO subareas 2 and 3 (upper diagram), the corresponding fisheries effort (middle diagram) and standardized catch rates related to 1967 (lower diagram), after Atkinson (1984).

the decrease of the water temperature observed in recent years in the western North Atlantic. At depths between 400 and 1100 m, grenadiers and Greenland halibut occur in mixed concentrations. The decrease of the water temperatures has led to a considerable increase of the density of the Greenland halibut. Off Baffin Island, during years with low water temperatures, Burmakin (1978), too, found an increase of Greenland halibut catches and a decrease of grenadier catches, and during years with relatively high water temperatures, the reverse situation. In Canadian waters, there exists a regulation, according to which, in directed grenadier fishing, the by-catches of Greenland halibut may not exceed 10 per cent. Due to the increase in the density of the Greenland halibut, the fishery vessels are forced to move away to grounds with greater depths, where more grenadiers than Greenland halibut are present, but where the effectivity of fishery is relatively low (Atkinson, 1982; Bowering, 1983; Chumakov and Savvatimsky, 1983). For the fishery of the German Democratic Republic, Ernst (1984) has made observations similar to those reported by Chumakov and Savvatimsky. According to Ernst, the continuous changes in the hydrographic regime of the western North Atlantic with dropping water temperatures (cf. also Stein, 1982a; 1985) observed since about 1970 have led to a migration of the rock grenadier to greater depths and more southern areas. At the present time, the Greenland halibut populates, above all, the depths between 800 and 1200 m, where it may be encountered at its preferred water temperature of about $\pm 0^{\circ}\text{C}$, while the rock grenadier is found mainly at a lower level (fishing depth: down to 1500 m) at a water temperature around 4°C . This trend appears to have continued in 1983 to an increased extent; the cold waters of the Labrador Stream reach down to a depth of 1100 m. The zoning of the occurrence of the Greenland

halibut in the higher water zones with increase of grenadier density at greater depths has been described also by Chumakov and Postolaky (1979).

For the rock grenadier in the area between Baffin Island and western Greenland (ICNAF/NAFO subareas 0 and 1), Borrmann (1976; 1977; 1978) has calculated a MSY of 7000 to 9000 t/year. Similar data have been presented by Parsons et al. (1978) and Atkinson (1979; 1980). The catches made during the period between 1967 and 1980 varied between 1100 and 8500 t/year (only in 1974 did the catches reach a level of 12,318 t), with an average yearly catch of 5800 tons. However, beginning with 1981, these catches decreased to very low levels. During the years up to 1977, the catches were brought ashore mainly by vessels of the U.S.S.R. According to statistical data for the years 1978 to 1980, catches made by vessels of the Federal Republic of Germany occupied the first position; however, we have expressed some doubt regarding these data already on page 2 [of the original text]. Beginning in 1975, the ICNAF, in order to prevent further extension of fishery, introduced a TAC of 10,000 tons, which was upped to 14,000 tons in 1976, but was reduced again to 8000 t/year on the basis of Borrmann's (1976) calculations. The catch quote has remained at that level to this date.

No comparable stock estimates have been made and no protective measures have been introduced for the grenadier of the eastern North Atlantic.

3.8. Mesh selection

Nikeshin et al. (1981), Konstinov et al. (1982) and Junge et al. (1982) have reported the first results of studies on mesh selection in bottom trawls with fish bags in grenadier fishery in ICNAF/NAFO subareas 3K and 2H. The selection factors of 2.39, 2.24, and 4.20 determined in those experimental studies differ so greatly that additional data have to be obtained before any useful data can be derived.

3.9. Products

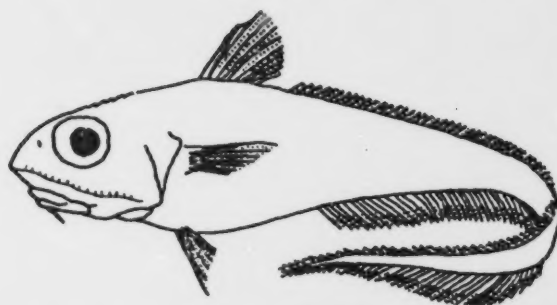
The rock grenadier has white, very tasty flesh, that is more firm than that of the cod, and is well suited for preparing fried and cooked dishes. Unfortunately, the tail makes up about half of the total length of this fish, and the utilizable portion is limited almost entirely to the anterior third of the fish. After decapitation, gutting, and removal of the tail portion, there remains, on average, only 48 per cent of the whole body weight according to Christians (1976). The water content of that portion amounts to about 79 per cent; the fat content is only 0 - 0.6 per cent. In the specimens examined, the liver made up 6.5 per cent of total weight, and was very rich in fats with 75 per cent. In grenadiers measuring 72 to 95 cm in length, the yield of fillet, in hand filleting operation, amounted to only 22 - 23 per cent. Thirty-two per cent of the whole fish could be processed into farce (minced fish). That minced fish is processed further into fish sticks, fish steaks, etc. Smoked pieces of this fish (yield: about 30 per cent or less) were evaluated as very good [in taste tests]. Lefranc (1977) has reported on experimental processing of grenadiers with the aid of machines.

4. Roughhead grenadier (*Macrourus berglax* Lacépède)

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The roughhead grenadier is distinguished from the rock grenadier, above all, in that its entire body¹ is covered with massive, firmly attached scales. For that reason, this fish is also called "Panzergrénadier" by [German] fishermen. The color of this fish is ashy gray, somewhat darker at the pectoral part. The anal fin has a dark edge.¹ The size may be up to one meter.
¹ The eyes are larger than in the rock grenadier.

*) Translator's note: Panzer = armour



Macrourus berglax

Figure 25 - Roughhead grenadier

4.1. Distribution (Range)

The distribution of the roughhead grenadier is similar to that of the rock grenadier (Figure 26). Its range extends from the east coast of [North] America south of Georges Bank by way of the waters off Labrador, Davis Strait, western and eastern Greenland, Iceland, the Faroe Islands to Spitsbergen and into the Barents Sea to 82°N (Marshall and Iwamoto, 1973). This fish occurs along the continental slopes of the subarctic and temperate waters.

According to Parsons (1976), this fish is found in the western North Atlantic, above all, along the eastern edge of the Grand Bank off Newfoundland (NAFO subareas 3L and 3N) and off Labrador (Figure 27). In the areas mentioned first, this fish was taken at depths between 320 and 775 m at water temperatures of 1 to 4°C, with the greatest concentration found at a depth between 320 and 500 m at a water temperature of 2 - 3.5°C. The best catches off Labrador were made at depths between 183 and 460 m. On the whole, the roughhead grenadier is distributed, at relatively low density, over a range considerably greater than that occupied by the rock grenadier. The scientific catches of the Canadian fisheries vessel "A.T. Cameron" made during the years 1958 - 1978 rarely exceeded 450 kg/hour.

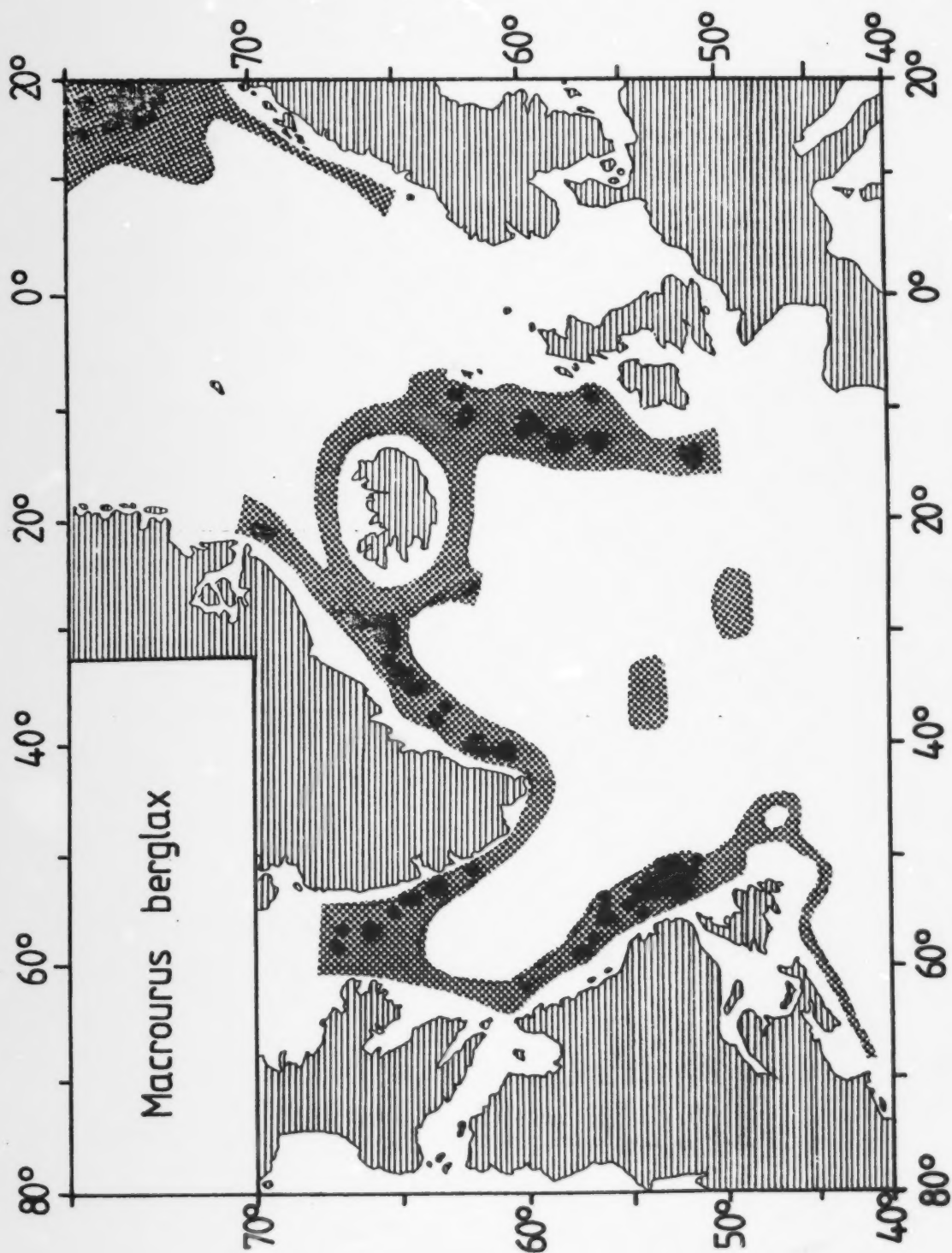


Figure 26 - Distribution of the roughhead grenadier in the North Atlantic. The black dots indicate the fishing grounds visited by fisheries research ships "Anton Dohrn" and "Walther Herwig."



Figure 27 - Distribution of the roughhead grenadier in front of the coast of Canada according to research catches (from Parsons, 1976b).

According to Savvatimsky (1984), roughhead grenadiers have been taken along the continental slope at all depths between 300 and 1000 m in Soviet long-line trawling trials, with the best catches made between the Grand Bank (off Newfoundland) and the Flemish Cap at depths of 400 to 500 m. Below 700 m, this fish was taken only infrequently. The larger individuals were found at greater depths. This observation, however, contradicts data provided by Parsons (1976b), according to which the smaller grenadiers may be

found along the continental slope south of Newfoundland in the deeper and warmer waters below the large specimens.

French research vessels took roughhead grenadiers in ICNAF/NAFO subareas 2J and 3K - 3L at depths of between 235 and 940 m (Geistdoerfer, 1979). The size of these catches amounted maximally to 540 kg/30 minutes trawling time (Maucorps and Fontaine, 1979).

In the course of German studies on fishery research vessels "Anton Dohrn" and "Walther Herwig" off Labrador (subarea 2J)—which studies were directed mainly at the Atlantic cod—roughhead grenadiers were taken at depths between 184 and 660 m (maximal fishing depth) (Mombeck, 1981; 1983; 1984; Sahrhage, 1982). The water temperatures at these fishing depths were 0.3 to 3.9°C. These scientific catches were greatest at depths between 300 and 500 m, amounting, on average, to about 40 kg/trawling hour. During the period of October and November of 1983, it was found that the zone of maximal catches had shifted into the 200 - 300 m range, probably due to a change in the hydrographic situation. The greatest catch, taken in November of 1980, amounted to 380 kg/30 minutes trawling time, i.e. that catch was within the range found in the afore-mentioned French studies.

Forest et al. (1978) have described the occurrence of M. berglax off Baffin Island, where the best catches were made at depths of between 190 and 370 m.

In the waters around Greenland, there exist considerable differences in the occurrences of roughhead grenadiers on the west side of the island and the east side, respectively. Off western Greenland, this fish—as the results of German scientific catches have shown—is encountered only infrequently. Roughhead grenadiers were taken there in quantities of up to 15 kg/30 minutes trawling time at depths of between about 250 and 740 m, with most fishes taken below 400 m at water temperatures between 2.2 and 2.7°C. No data are available regarding the occurrence in deeper waters, since fishing was not

attempted at these levels. On the other hand, the quantities of this fish taken in German scientific catches off eastern Greenland were considerably greater (Figure 26). In these waters, M. berglax is distributed, above all, over the area of the Dohrn Bank, and is taken there at depths of between about 350 and 800 m in quantities of up to 50 kg/trawling hour. Occasionally, the scientific catches were as high as 100 to 120 kg/hour; one haul of the fishery motor vessel "Karlsburg" (chartered for research work) carried ^{out} during October of 1980 at a depth of 800 m led, in fact, to a catch of 886 kg over 30 minutes of trawling (Figure 29). In zones of good catches, the bottom water temperatures amounted mostly to 3 - 3.7°C, indicating that the roughhead grenadier prefers the colder waters of the eastern Greenland Stream (cf. p. [omitted in the original]). Commercial catches of this species by German deepsea fishery coming from the area of the Dohrn Bank represent by-catches of fishery directed at redfish (cf. page 7). In the remaining waters off eastern Greenland, above all in the southeast, the density of occurrence of this grenadier appears to be considerably less marked, since scientific catches there did not exceed a few kg/hour.

These particular observations made off eastern Greenland are largely in agreement with the results published by Magnusson (1977; 1978; 1978a; 1980; 1981; 1983), describing the occurrence of M. berglax, in particular, in the area of the Dohrn Bank, near Vikurall, but also near Mösting and on to the eastern Reykjanes Ridge. According to Magnusson, this grenadier may be encountered around the Dohrn Bank at depths of between below 300 m and about 1250 m, with maximal stock density at 700 - 800 m (Figure 28).

Off Iceland, the roughhead grenadier is distributed, above all, in the west and northwest; however, this fish occurs also in the other waters around that island (Magnusson, l.c.; and 1979). On the whole, the range

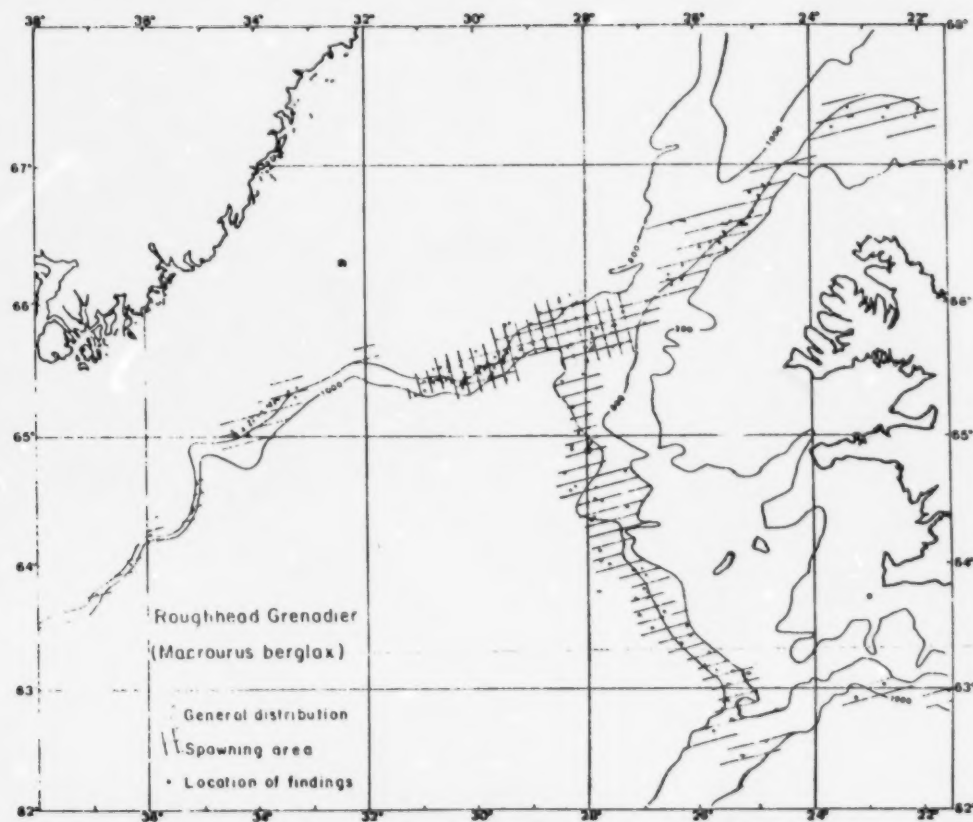


Figure 28 - Distribution of the roughhead grenadier between Greenland and Iceland (from Magnusson, 1978).

is more extensive than that of *C. rupestris*, but its numbers are considerably smaller. The catch depths are found mainly at between 500 and 800 m at water temperatures of, usually, 3 to 5°C.

In the area of the Rosegarden between Iceland and the Faroe Islands, Kotthaus and Krefft (1967) took a few *M. berglax* individuals at depths between 450 and 760 m at water temperatures of between 2.8 and 4.2°C. Other German scientific catches east of the Faroe Islands also contained rough-

Likewise, in the bottom trawl fishery of the fishery research vessel "Walther Herwig" in the deeper zones along the continental slope west of the British Isles and Ireland, M. berglax was netted at depths of between 500 and 1250 m in single specimens up to a few kilograms. The water temperatures at these fishing depths there amounted to between 1.0 and 9.2°C.

According to Gushchin and Kukuev (1980), one single specimen of M. berglax was caught in Soviet fishery trials on the northern part of the mid-Atlantic Ridge at positions 45°50'N, 29°33'W and 34°33'N, 35°20'W (Figure 26).

The roughhead grenadier is widely distributed on the continental shelf off Norway (Bakken et al., 1975; Eliassen, 1983a; 1983b)); it is present likewise in the deeper fjords of the Finmark (Collett, 1904; Hognestad and Vader, 1979). This fish is utilized commercially as by-catch in Norwegian gillnet, longline and trawl fishery for Greenland halibut. These catches are made at depths of between 500 and 900 m, and are best at a depth of between 600 and 800 m, where the water temperatures measured vary between 1 and 4°C.

M. berlax has been taken also in a number of deepers basins in the Barents Sea north of Ingø and east of Vardø (Collett, 1904; Eliassen and Falk-Petersen, 1984). Nizovtsev et al. (1976) have reported on the occurrence of this species at great depths (1450 - 2300 m) in the Sea of Norway at positions 72°30'N, 15°00'E and 71°50'N, 11°30'E.

German investigations in the waters around Bear Island and Spitsbergen have demonstrated that roughhead grenadiers were taken from the waters off the North Cape to northwestern Spitsbergen (about 80°N) in small quantities consisting of a few specimens to 10 kg/30 minute hauls. The catch quantities were only rarely greater (up to 43 kg/30 min.). At fishing depths between 250 and 520 m, the water temperatures amounted to between -1°C and 3°C. According to Reinsch and Stein (1985), the 401-500 m zone is preferred by this fish.

Geistdoerfer (1979) found M. berglax between Bear Island and Spitsbergen at depths between 465 and 818 m.

Comparison of the respective distributions of the two grenadiers under discussion reveals that their ranges overlap to a considerable extent. However, C. rupestris prefers the deeper zones along the shelf slopes with relatively warm water temperatures, while M. berglax is concentrated usually in the zones above the latter ones, i.e. in the zones with lower water temperatures (0 - 4°C).

4.2. Length and age composition

In the case of the roughhead grenadier, we are faced with the same difficulties in measuring length as in that of the rock grenadier (cf. p. 23). For that reason, the pre-anal length or, more recently, the pre-anal fin length is frequently measured also in this species. However, the length composition is in most publications given as the total length (TL) of the fish.

For conversion from pre-anal length to TL, Kosswig (1979) found in M. berglax taken off eastern Greenland the relation

$$TL = \text{pre-anal length} \times 2.2769 + 9.3124.$$

Cornus, Reinsch and Schellenberg (unpublished data) calculated for the roughhead grenadier from the western Barents Sea and Spitsbergen the relation

$$TL = \text{pre-anal length} \times 2.4247 + 4.1777.$$

The length compositions of catches of roughhead grenadiers taken on various fishing grounds are compiled in Figure 29. In the bottom-trawl catches of the fishery research vessel "Walther Herwig" off southern Labrador (NAFO area 2J), the fish, on average, were considerably smaller in 1979

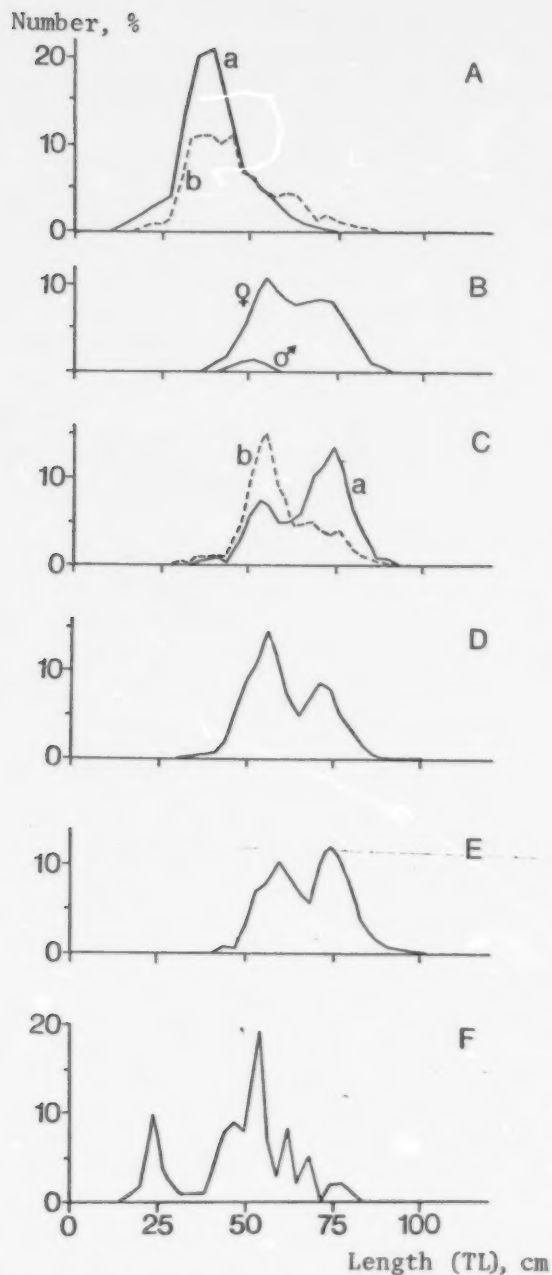


Figure 29 - Length composition of the roughhead grenadier

- A: Southern Labrador (NAFO area 2 J). a: fisheries research vessel "Walther Herwig," 1979, $\bar{n}$ = 1687. b: fisheries vessel "Ernst Haeckel," 1978, $\bar{n}$ = 777 (after Berth et al., 1979)
- B: Eastern Newfoundland Bank, 1982 (after Savvatimsky, 1984)
- C: Eastern Greenland (Dohrn Bank). a: fisheries motor vessel "Karlsburg," 1980, $\bar{n}$ = 329. b: fisheries research vessel "Walther Herwig," 1982, $\bar{n}$ = 1009
- D: Eastern Greenland (Dohrn Bank), 1976, $\bar{n}$ = 3748 (after Magnusson, 1978)
- E: Iceland, 1976, $\bar{n}$ = 941 (after Magnusson, 1978)
- F: Spitsbergen, 1979, fisheries research vessel "Walther Herwig," $\bar{n}$ = 129

than on the eastern North Atlantic fishing grounds. The length curve is in very good agreement with the results obtained in catches made on the same grounds in 1978 by the research vessel "Ernst Haeckel" of the German Democratic Republic (Berth et al., 1979) (Figure 29, A). A similar length composition was observed also during subsequent voyages. On the other hand, the catches taken in 1982 with longlines on the eastern Newfoundland Bank (NAFO area 3), according to Savvatimsky (1984), consisted of larger individuals measuring mostly 50 to 80 cm in length (Figure 29, B). This difference would be attributable to the use of different fishing gears.

In the eastern North Atlantic, the trawl catches of this grenadier consist primarily of specimens measuring > 50 cm in length. The length compositions of the fish taken from the waters off eastern Greenland (Dohrn Bank) and off Iceland turned out to be very similar (Figure 29, C - E). These curves show, for 1976 and 1980, bimodal courses with peaks at about 55 - 60 cm and 75 cm, respectively. Magnusson (1980), too, found in the grenadiers taken on the Dohrn Bank in 1978 a length distribution very similar to that shown in Figure 29, D for 1976. In the catches taken by the fishery research vessel "Walther Herwig" off eastern Greenland in 1982, on the other hand, only one peak at about 55 cm was evident (Figure 29, C, broken curve). The length composition in 1983 in the same area was very similar. Specimens measuring < 40 cm were seen only in small numbers, and specimens < 23 cm were seen not at all.

According to Eliassen's (1983b) investigations, the grenadiers taken along the shelf slope off the coast of Norway in longline and gillnet catches exhibit mostly lengths of 50 to 85 cm. However, considerable differences in the courses of the curves are evident in the different study areas.

Length measurements of M. berglax in the waters off the western and eastern coasts of Spitsbergen carried out on the fishery research vessel "Walther Herwig" in 1979 (Figure 29, F) have shown that most of these grenadiers measured between 40 and 75 cm in length. Unfortunately, only 129 specimens were available for study. In this instance, the share of small specimens measuring between 17 and 30 cm in length is worthy of note. The fishing depth was 370 - 490 m at water temperatures close to the bottom of -0.9 to 2.3°C.

Age determination is associated in the roughhead grenadier with difficulties similar to those encountered in C. rupestris (cf. p. 32). Scales are better suited for that purpose than otoliths, if the scales are impregnated with silver nitrate solution (0.5 to 1.5%) and examined under polarized light (Kosswig, personal communication). The best scales may be found on the abdomen of this fish, since the largest ones are present there, and the zones of annual rings can be better identified on them (Figure 30).

The results of age determinations show that the catches consist of grenadiers six to 25 years old (Figure 31). The longline catches on the eastern Newfoundland Bank (Savvatimsky, 1984) as well as the commercial gillnet catches off northern Norway (Eliassen, 1983) contained relatively large numbers of older grenadiers, while the trawl-net catches off eastern Greenland contained a considerably greater share of younger fish, and the oldest grenadiers there were 21 years old (Kosswig, 1980a; 1981; 1984; in the press). According to the results reported by Savvatimsky (1984) and Eliassen (1983), the males, on average, are considerably younger than the females (Figure 31, upper part and lower part of the diagrams).



Figure 30 - Scale of roughhead grenadier impregnated with silver nitrate solution, under polarized light (Photo: Kosswig/Schumacher).

Number (%)

- 70 -

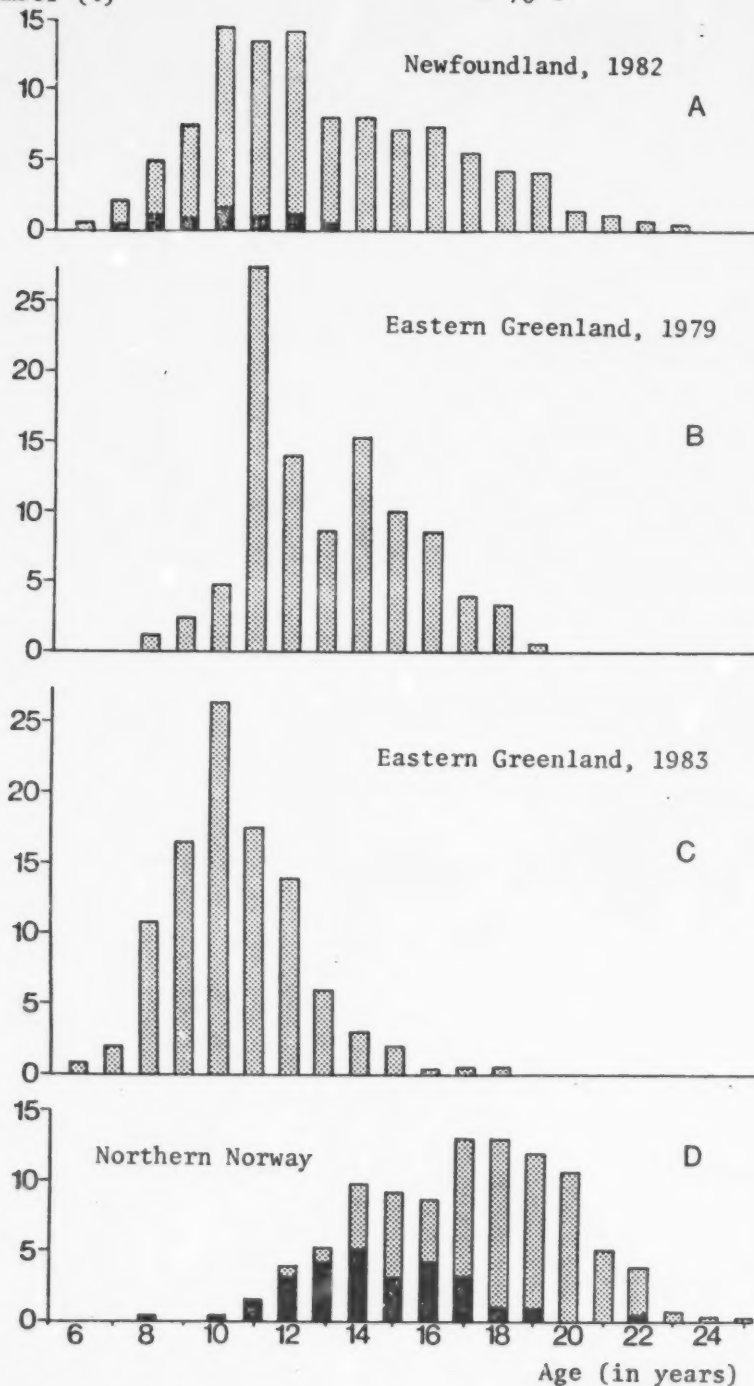


Figure 31 - Age composition of roughhead grenadier.

A: Eastern Newfoundland Bank, 1982, from long-line trawling, $n = 341$ (after Savvatimsky, 1984)

B: Eastern Greenland, 1979, from trawling, $n = 473$ (after Kosswig, 1981)

C: Eastern Greenland, 1983, from trawling (after Kosswig, in the press)

D: Northern Norway, 1981, from gillnetting, $n = 222$ (after Eliassen, 1983b)

The dark parts of the columns in A and D represent the shares of males.

4.3. Growth

Data on the growth of the roughhead grenadier are rare so far. A curve on the length-weight relation in grenadiers off the eastern Newfoundland Bank (Figure 32) has been published by Savvatimsky (1984). According to his investigations, the females grow more rapidly than the males—at least in the case of grenadiers seven years old and older. The growth curves for length and weight of the females are shown in Figure 33. According to these curves, females with a TL of 50 cm are about nine years old; those measuring 80 cm in length are about 21 years old. The material available is not adequate for plotting a representation of the growth of the males. In M. berglax taken off northern Norway, Eliassen (1983b) found that the mean age of the males was 3.7 years lower than that of the females. When we compare Savvatimsky's (l.c.) data with the data published by Kosswig (1981; 1983) on M. berglax from eastern Greenland, we find for the 8- to 12-year-old grenadiers a good agreement of the mean lengths within the age groups.

4.4. Reproduction

According to Yanulov's (1962) studies, the ovaries of mature grenadiers taken off Norway during January contained about 25,000 eggs. The mature eggs exhibited a diameter of 3.4 - 3.85 mm. In addition to these eggs, two further size groups of eggs—measuring 0.5 - 1.1 and 2.3 - 2.75 mm, respectively—were found to be present in the ovaries, leading Yanulov to conclude that eggs may be released several times during the course of the year. According to Eliassen and Falk-Petersen (1985), fecundity depends on body size. The latter authors counted between 2000 and 71,000 eggs per ovary, and also found three size groups of oocytes. The mature eggs are large (measuring between 3 and 4.5 mm in diameter) and rich in yolk. The mean diameter of the eggs measured by Magnusson (1978) was 3.66 mm.

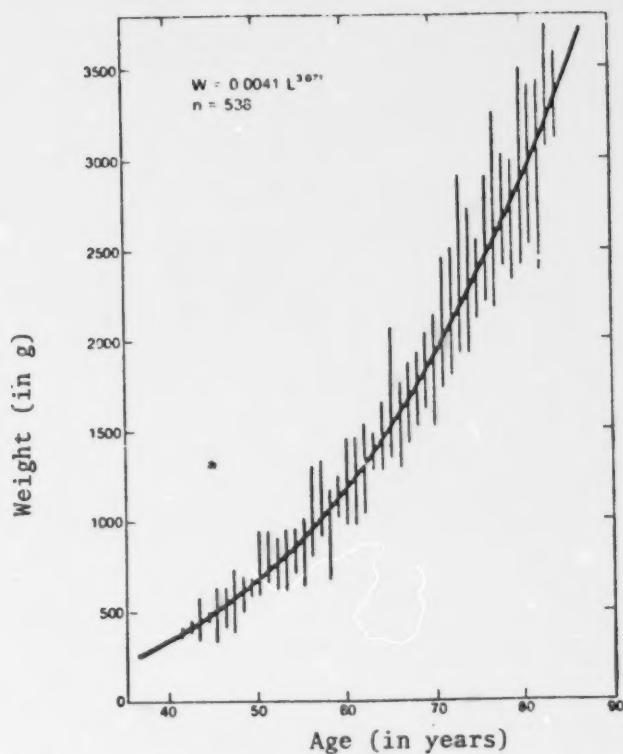


Figure 32 - Length/weight relations in females of roughhead grenadier from the eastern Newfoundland Bank, 1982 (from Savvatimsky, 1984)

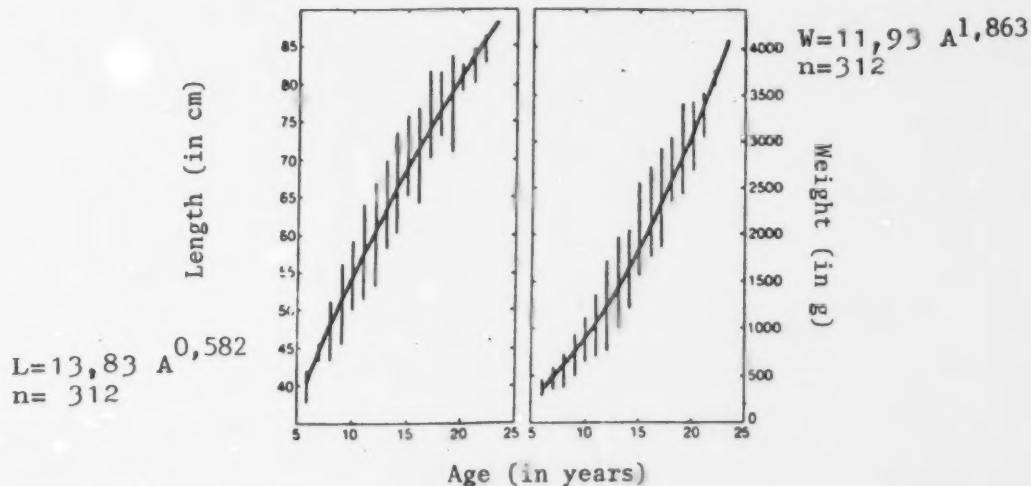


Figure 33 - Relations between age and length (left diagram) and between age and weight (right diagram) in female roughhead grenadier from the eastern Newfoundland Bank, 1982 (from Savvatimsky, 1984)

As in C. rupestris, the spawning period of M. berglax also covers a large part of the year. In the western North Atlantic (NAFO areas 3K, 3L, and 2J), Geistdoerfer (1979) found that, during the middle of July, 1.3 per cent of the males and 5.1 percent of the females were still spawning, while > 90 per cent of the adults were spent and were in the sexually inactive stage. The spawning grenadiers were encountered at a depth between 390 and 430 m. In that area, the spawning period would begin between the end of spring and early summer. During January and February, only a few adult specimens were found to be in the advanced stage of oogenesis (four per cent of the females). During the summer as during the winter, the grenadier catches exhibited a large share of sexually immature specimens: during the summer, 71 per cent of the males were juveniles, during the winter, 98 per cent were juveniles. In the case of the females, 34 per cent were sexually immature during the summer, and 76 per cent during the winter. Following his investigations during May to July of 1982, Savvatimsky (1984) concluded that spawning along the edge of the Newfoundland Bank—in particular, along the shelf slopes facing south and southeast—takes place during the winter and early spring.

In the eastern North Atlantic, Magnusson (1977; 1978) found spawning grounds west and northwest of Iceland, near Vikurall and on the Dohrn Bank (Figure 34). On the basis of the seasonal distribution of the maturing and mature stages and the occasional observation of spawning grenadiers, we are permitted to conclude that spawning there takes place mainly between February and May. Deep plankton catches close to the bottom at a depth of 875 - 1200 m yielded, during March of 1978, eggs of M. berglax in many hauls. North of 65°N, spawning appears to be considerably more intensive than south of that latitude. However, Magnusson (1977) found also evidence suggesting that spawning takes place during the winter—November to February—

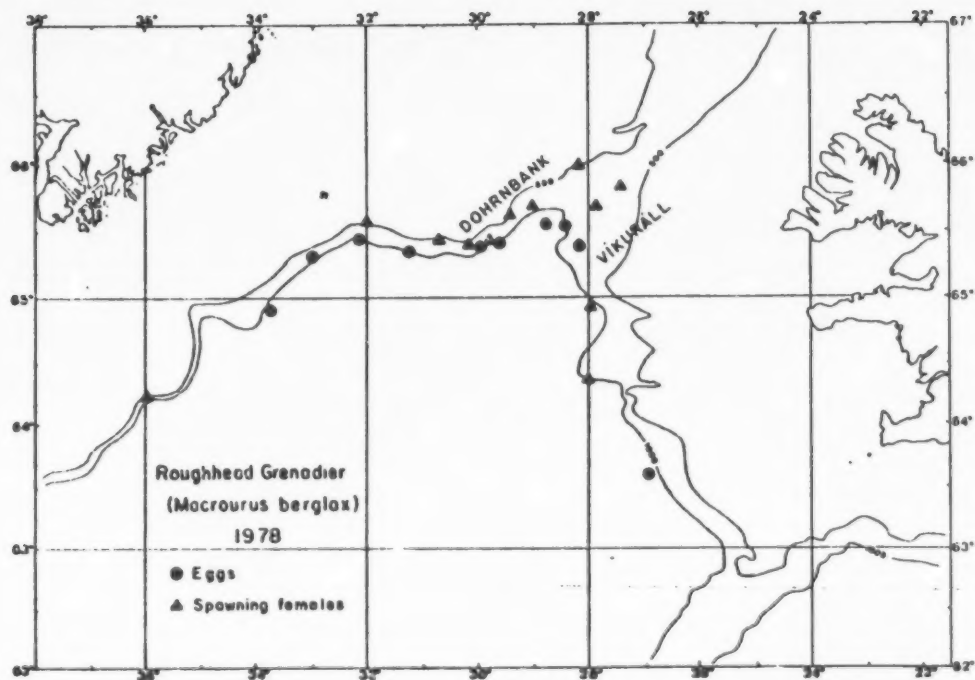


Figure 34 - Spawning grounds of roughhead grenadier between Iceland and Greenland (from Magnusson, 1978)

so that the spawning time covers a long period, perhaps even the entire year. In German investigations off eastern Greenland—mainly in the area of the Dohrn Bank—the gonads of grenadiers exhibited during September and October signs of renewed maturation (Kosswig, personal communication).

According to Geistdoerfer (1979), mature and spawning females were still found during the middle of June on the Iceland-Foroese Ridge, on which basis the author concluded that one spawning period ends late in spring.

In roughhead grenadiers from the waters off the coast of Norway. Eliassen (1983b) found, in large specimens measuring > 65 cm in length, an increase of ovarial weight from May to December. There spawning takes place during the winter, with a probable peak during January (Eliassen and Falk-Petersen, 1985). This finding is in agreement with those reported by Yanulov (1962). Females with a small number of mature eggs in their ovaries, however, were observed also during the period between July and September, and males with mature sperm were found [at that time], so that a second, shorter spawning period during the late summer/early fall can not be excluded.

On the Kopytov Bank southwest of Bear Island, Savvatimsky (1969) found, during May at a depth of 570 m, females with mature eggs ready to spawn. That author, too, concluded that the spawning period was a very long one.

The shares of females and males in the grenadier catches vary greatly, and no consistent trend associated with water depth can be identified (Geistdoerfer, 1979). Magnusson (1978a; 1979; 1983; 1984) has established that, off Iceland, the females predominate in numbers, on average, with 54 to 56 per cent, while, off eastern Greenland, the males represent the greater share, occasionally making up even 82 per cent of the catches. In the long-line catches investigated by Savvatimsky (1984) off the eastern part of the

Newfoundland Bank, 94 per cent of the grenadiers taken were females. The gillnet catches investigated by Eliassen (1983b) contained up to 72 per cent females. The pronounced preponderance of females would in both instances be attributable to the catching gear used, which retain particularly many older grenadiers (Figure 31).

The onset of sexual maturity occurs in M. berglax, as it does also in the other grenadier species, rather late in life. According to Eliassen and Falk-Petersen (1985), among the female grenadiers taken off Norway, all 14-year-old individuals were still juvenile; among the 15-year-old ones, about half were sexually mature; beginning with the age of 18 years, all individuals were adult.

Our present knowledge regarding the distribution of the juvenile stages of M. berglax is extremely sparse. One specimen of the 0 group measuring 47 mm in length was taken during August of 1982 at a depth of 50 m off the coast of eastern Greenland at 62°N (Vilhjalmson and Magnusson, 1982).

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4.3. Food

The roughhead grenadier is a benthopelagic predator, which, as juvenile, feeds mainly on organisms on the bottom of the sea [in particular, Mollusca, serpent stars (Ophiuridae), and bristleworms (Polychaeta)]; with onset of sexual maturity, i.e. once this grenadier has reached a length of 60 to 65 cm, it will take to an increasing extent pelagic food (crustaceans and fishes).

Results of qualitative diet investigations have been published by Konstantinov and Podrazhanskaya (1972), Geistdoerfer (1976; 1979b), Savvatimsky (1984) as well as by Eliassen and Jobling (1985).

Among the crustaceans, Pandalus borealis, amphipods and Euphausiidae, in particular, are of importance for this grenadier as prey animals; among the Mollusca, Buccinum and cephalopods. The stomachs of large grenadiers were rather frequently found to contain conspecifics as well as Atlantic argentine (Argentina silus), redfish and other fish species.

4.6. Parasites

Zubchenko (1981) found 20 species of parasites in roughhead grenadiers taken from the western North Atlantic. Representing six of these species, the trematodes were qualitatively most widely distributed. Their presence indicates that the dietary spectrum of this grenadier is a wide one. As Table 5 demonstrates, infestation in the two areas investigated—the Flemish Cap (NAFO subarea 3M) and off southern Labrador (NAFO subarea 2J)—differed very greatly. In the former area, the number of parasitic species was relatively small, while the parasitic fauna contained a considerably greater number of species off southern Labrador. Zubchenko has attributed this difference to the fact that the grenadiers off southern Labrador were taken from depths of 400 to 600 m, while those on the Flemish Cap were taken at a depth of 1200 - 1300 m, i.e. a zone where less food is available. Specific parasites of M. berglax are Zschokkella kudoi, Davisia newfoundlandia, Cyclocotyloides pinguis and Clavellonimus macrouri.

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4.7. Stock size and utilization

Estimations of the M. berglax stocks are ^{hitherto} available neither for the western North Atlantic nor for the eastern North Atlantic, and no specific management measures have been implemented for this fishery. It must, however, be remembered that the grenadier catches brought ashore and classified as

Table 5 - Parasitic fauna found in roughhead grenadier. Numbers and percentages of infested fishes. N = Number of fishes examined (after Zubchenko, 1981)

Parasites	Flemish Cap		South Labrador	
	$N = 15$		$N = 15$	
	No	%	No	%
1. <i>Zschokkella kudo</i>	-	-	4	26.6
2. <i>Auerbachia pulchra</i>	2	13.3	7	46.6
3. <i>Davisia newfoundlandia</i>	-	-	1	6.6
4. <i>Cyclocotyloides pinguis</i>	2	13.3	-	-
5. <i>Philobythos atlanticus</i>	-	-	2	13.3
6. <i>Scolex pleuronectis</i> l.	-	-	3	20.0
7. <i>Pseudophyllidea</i> gen.sp.1.	-	-	1	6.6
8. <i>Lepidapedon elongatum</i>	-	-	2	13.3
9. <i>Hemirurus levinsoni</i>	-	-	1	6.6
10. <i>Derogenes varicus</i>	2	13.3	2	13.3
11. <i>Gonocerca crassa</i>	-	-	8	53.3
12. <i>Lecithophyllum bothriophoron</i>	-	-	1	6.6
13. <i>Genolinea laticauda</i>	-	-	8	53.3
14. <i>Contracaecum aduncum</i>	11	73.3	10	66.6
<i>Contracaecum aduncum</i> 1.	-	-	6	40.0
15. <i>Anisakis</i> sp.1.	-	-	2	13.3
16. <i>Capillaria kabatai</i>	-	-	3	20.0
17. <i>Echinorhynchus gadi</i>	7	46.6	11	73.3
18. <i>Rebelula bonvieri</i>	1	6.6	1	6.6
19. <i>Clavella adunca</i>	7	46.6	7	46.6
20. <i>Clavellomimus macrouri</i>	6	40.0	1	6.6

"grenadiers" consist—not only in the Federal Republic of Germany, but also in other countries—to a rather considerable extent not of C. rupestris, but of M. berglax. Unfortunately, these two species are not listed separately in fishery statistics (cf. Section 2.).

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